MECHANICAL DESIGN OF HYDRO PLANTS

TENNESSEE VALLEY AUTHORITY PROJECTS

UNITED STATES
TENNESSEE VALLEY AUTHORITY

DESIGN OF TVA PROJECTS

TECHNICAL REPORT NO. 24

VOLUME 3

Mechanical Design of Hydro Plants

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Technical Reports Nos. 1, 2, and 3 were out of print at the time of this publication.

TENNESSEE VALLEY AUTHORITY,
Knoxville, Tenn., December 10, 1958.

Mr. A. J. WAGNER, *General Manager,*
Tennessee Valley Authority, Knoxville, Tenn.

DEAR MR. WAGNER: Technical Report No. 24, Volume 3, *Mechanical Design of Hydro Plants*, is the sixth of a series of special reports being prepared to cover certain phases of engineering and construction work common to all projects designed and constructed by TVA in the unified development of the water resources of the Tennessee River system. The previous two volumes of this report cover (1) Civil and Structural Design and (2) Electrical Design.

These special technical reports have been planned as a companion series to technical reports on the individual projects and record the results of experience gained on TVA projects in specialized fields over a period of years. It is recommended that Technical Report No. 24, Volume 3, be printed as a public document.

Yours very truly,

GEO. K. LEONARD, *Chief Engineer.*

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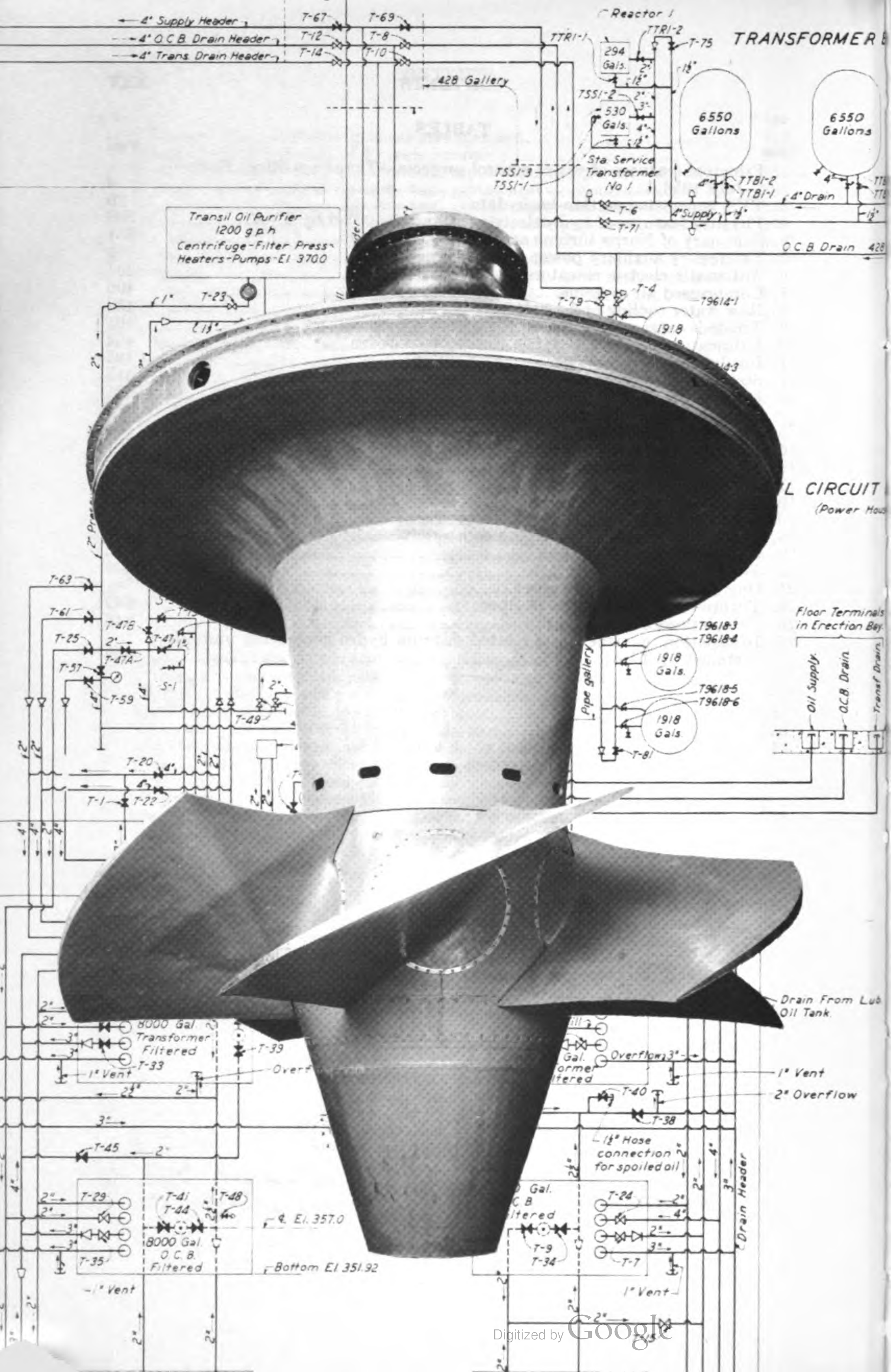
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4" O.C.B. Drain Header
4" Trans. Drain Header
T-67
T-69
T-12
T-8
T-14
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428 Gallery
Reactor 1
TTR1-1
TTR1-2
T-75
294 Gals.
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530 Gals.
6550 Gallons
6550 Gallons
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MECHANICAL DESIGN OF HYDRO PLANTS

Tennessee Valley Authority Projects

CHAPTER 1

INTRODUCTION

This is the third of three volumes comprising the *Design of TVA Projects* and is one of a planned series of special technical reports recording the experience of TVA in carrying out the major phases of its engineering and construction program in connection with its hydroelectric projects. The civil and electrical activities of the TVA's Division of Design have been covered in previously issued volumes: Volume 1, *Civil and Structural Design;* volume 2, *Electrical Design of Hydro Plants.* Some of the introductory and explanatory text contained in those two volumes is repeated in volume 3. This is done so that volume 3 will be complete in itself as well as a component of the series on design of hydroelectric plants. This third volume explains the engineering work involved in the design of the mechanical installations for the primary water control structures of TVA, including switchyards constructed at the generating stations. Appurtenances for the control of water, such as gates and cranes, are considered to be accessories of the structures and were included in volume 1.

When TVA was created by an act of Congress on May 18, 1933, it was specifically authorized to construct water control projects to maintain a 9-foot navigation channel from the mouth of the Tennessee River to Knoxville, Tenn.; to provide for the control of floods; to generate electricity from the power made available by the water control structures; and to provide other related benefits. By 1954, TVA, in carrying out this program, had completed 20 major dams. These included 7 (Kentucky, Pickwick Landing, Wheeler, Guntersville, Chickamauga, Watts Bar, and Fort Loudoun) on the main river and 13 (Apalachia, Hiwassee, Chatuge, Ocoee No. 3, Nottely, Norris, Fontana, Douglas, Cherokee, Watauga, South Holston, Boone, and Fort Patrick Henry) on tributaries. Of these 20 dams, 9 were initially completed with vacant stalls for future units and 2 were completed without powerhouses. By the middle of 1956, however, generating units were in operation in all these stalls and in the powerhouses added to the two dams.

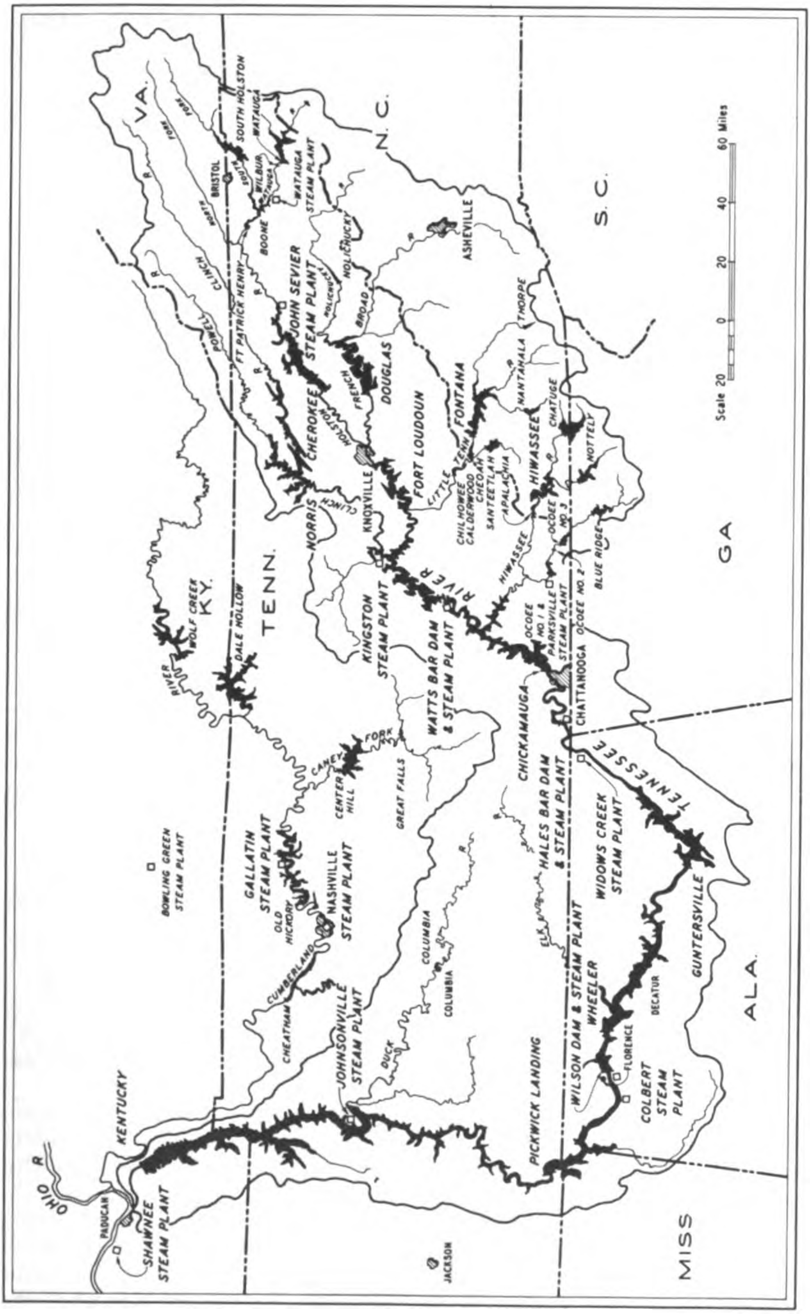

FIGURE 1.—*The Tennessee River Basin.*

There are at present (1958) 31 major dams which make up the integrated water control system of the Tennessee Valley. In addition to the 20 TVA-built dams listed above, 5 others (Wilson, Hales Bar, Ocoee Nos. 1 and 2, and Blue Ridge) were acquired by TVA and 6 (Calderwood, Cheoah, Thorpe, Nantahala, Santeetlah, and Chilhowee) are owned by the Aluminum Co. of America (ALCOA). There are also 13 relatively small hydro power projects (3 acquired by TVA and 10 owned by ALCOA) in the Tennessee Valley system. By agreement, TVA directs the storage and release of water through the ALCOA projects. Figure 1 shows the drainage area and location of the major projects of the Tennessee River system; figure 2 shows the profiles; and table 1 gives the principal features of the hydro projects.

The Tennessee Valley power system also receives and distributes power generated at six dams in the Cumberland Valley. These are Great Falls Dam on Caney Fork River, owned by TVA, and five U.S. Corps of Engineers projects—Wolf Creek, Old Hickory, and Cheatham[1] on the Cumberland River, Dale Hollow on the Obey River, and Center Hill on Caney Fork River. Power from these Corps of Engineers' projects is received and distributed by TVA in accordance with the National Flood Control Act of 1944. Figure 1 shows the location of the Cumberland Valley projects.

[1] Scheduled for operation in 1959.

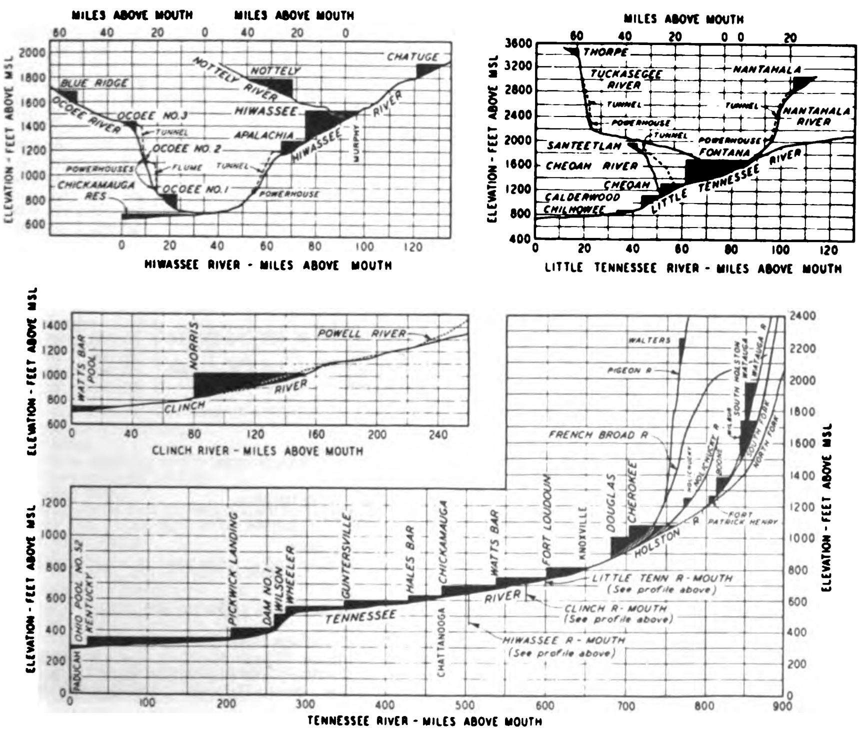

FIGURE 2.—*Profiles of Tennessee Basin rivers.*

TABLE 1.—*Principal features of water control*

Dam and appurtenances									
Project	Date of first use [a]	River	Maximum height (feet)[b]	Overall crest length (feet)	Maximum spillway capacity (cfs)[c]	Volume of concrete (cu. yds.)	Volume earth and/or rock fill (cu. yds.)[d]	Power [e] Installed capacity (kw)	Power [e] Ultimate capacity (kw)
Kentucky	1944	Tennessee	206	8,422	1,050,000	1,356,000	5,582,000	160,000	160,000
Pickwick Landing.	1938	do	113	7,715	650,000	679,100	3,081,000	216,000	216,000
Lock & Dam No. 1.	1926	do	22	233	([j])	([j])	([j])	0	0
Wilson	1925	do	137	4,535	796,000	1,280,000	0	436,000	436,000
Wheeler	1936	Tennessee	72	6,342	542,000	808,400	0	259,200	259,200
Guntersville	1939	do	94	3,979	478,000	308,600	874,900	97,200	97,200
Hales Bar	1913	do	112	2,315	224,000	([j])	([j])	99,700	99,700
Chickamauga	1940	do	129	5,800	470,000	506,400	2,793,500	108,000	108,000
Watts Bar	1942	do	112	2,960	560,000	480,200	1,210,000	150,000	150,000
Fort Loudoun	1943	Tennessee	122	4,190	390,000	586,700	3,594,000	128,000	128,000
Apalachia	1943	Hiwassee	150	1,308	136,000	[p] 237,800	0	75,000	75,000
Hiwassee	1940	do	307	1,376	[t] 112,000	800,600	0	[e]117,100	[e]117,100
Chatuge [u]	[v]1942	do	144	[w] 2,850	11,500	25,700	2,347,400	10,000	10,000
Ocoee No. 1	1912	Ocoee	135	840	[y] 45,000	160,000	0	18,000	18,000
Ocoee No. 2	1913	Ocoee	30	450	([j])	0	0	21,000	21,000
Ocoee No. 3	1943	do	110	612	95,000	[p] 82,500	82,000	27,000	27,000
Blue Ridge	1931	Toccoa	167	1,000	55,000	([j])	1,500,000	20,000	20,000
Nottely [u]	[v]1942	Nottely	184	[bb]2,300	11,500	21,700	1,552,300	15,000	15,000
Norris	1936	Clinch	265	1,860	[t] 93,400	1,002,300	181,700	100,800	100,800
Chilhowee [ee]	1957	Little Tenn.	91	1,373	182,000	91,500	307,000	50,000	50,000
Calderwood [ee]	1930	do	232	916	260,000	([j])	0	121,500	121,500
Cheoah [ee]	1919	do	225	750	200,000	([j])	0	110,000	110,000
Fontana	1945	do	480	2,365	[t] 134,300	2,815,500	760,600	202,500	202,500
Santeetlah [ee]	1928	Cheoah	212	1,054	76,100	([j])	0	45,000	45,000
Nantahala [ee]	1942	Nantahala	250	1,042	59,000	([j])	1,829,000	43,200	43,200
Thorpe [ee]	1941	Tuckasegee	150	900	56,000	([j])	1,060,000	21,600	21,600
Douglas	1943	French Broad	202	[ee]1,705	[t] 342,000	[p] 556,400	[p] 127,900	112,000	112,000
Nolichucky	1913	Nolichucky	([j])	([j])	([j])	([j])	([j])	10,640	10,640
Walters [ff]	1930	Pigeon	200	870	60,000	124,200	0	108,000	108,000
Cherokee	1942	Holston	175	[gg]6,760	[t] 286,000	694,200	3,304,100	120,000	120,000
Fort Patrick Henry.	1953	S. Fork Holston.	95	737	141,000	72,500	30,400	36,000	36,000
Boone	1953	S. Fork Holston.	160	1,532	137,000	198,400	714,000	75,000	75,000
South Holston	1951	do	285	1,600	[t,hh] 116,000	97,500	[p] 5,897,400	35,000	35,000
Wilbur	1912	Watauga	77	375	34,000	([j])	([j])	10,700	10,700
Watauga	1949	do	318	900	[t,hh] 73,600	80,400	3,497,800	50,000	50,000
Great Falls [ii]	1916	Caney Fork	92	800	[y] 150,000	([j])	([j])	31,860	31,860

[a] First unit placed in commercial operation.
[b] From deepest excavation on or near base line to roadway or deck.
[c] At maximum controlled pool level.
[d] Includes riprap.
[e] Based on rated capacity—unit 2 at Hiwassee is a reversible pump-turbine.
[f] From maximum controlled level to minimum expected pool level.
[g] At clearing line elevation.
[h] Except during drawdown in advance of floods at main-river plants.
[i] Head at maximum power storage level of tributary storage projects and average head at tributary run-of-river and main-river projects.
[j] No definite figure available.
[k] Two lifts. Work started July 2, 1956, on new 110- by 600-foot lock with single lift of 100 feet.
[m] At maximum allowable pool level.
[n] Applies to top of gates or flashboards. Maximum allowable pool elevation is 1 foot lower.
[p] Apalachia—An additional 210,600 cubic yards concrete in tunnel. Ocoee No. 3—An additional 28,500 cubic yards concrete in tunnel. Douglas—An additional 3,800 cubic yards concrete in saddle dams and dike; an additional 797,200 cubic yards fill in saddle dams and dike. South Holston—An additional 205,300 cubic yards fill in saddle dam.

projects—Tennessee River Basin—July 1958

Dam and appurtenances		Reservoir data and operating levels								
Lock										
Size (feet)	Maximum lift (feet)	Area at top of gates (acres)	Total volume below top of gates (acre-feet)	Useful controlled storage (acre-feet)[f]	Length of shore line (miles)[g]	Back-water length (miles)	Maximum controlled pool level (elevation)	Minimum expected pool level (elevation)[h]	Average tail-water level (elevation)	Head[i]
110 x 600	75	261,000	6,002,600	4,010,800	2,380	184.3	375	354	310	47
110 x 600	63	46,800	1,091,400	418,400	496	52.7	418	408	362	50
60 x 298	10	([j])	([j])	0	5	2.5	([j])	([j])	([j])	([j])
[k] 60 x 300 60 x 292	[k] 90	16,000	650,000	53,000	154	15.5	507.88	504.5	414	92
60 x 360	52	68,300	1,150,400	347,500	1,063	74.1	556.28	550	507	48
60 x 360	45	70,700	1,018,700	162,900	962	82.1	595.44	593	557	37
60 x 265	41	6,680	[m] 147,660	[m] 12,370	162	39.9	[n] 635	632	596	35
60 x 360	53	39,400	705,300	329,400	810	58.9	685.44	675	634	45
60 x 360	70	43,100	1,132,000	377,600	783	72.4	745	735	682	56
60 x 360	80	15,500	386,500	109,300	360	55.0	815	807	740	70
----------	-------	1,123	58,700	8,700	31	9.8	1,280	1,272	[r] 840	[s] 380
----------	-------	6,280	438,000	364,700	180	22	1,526.5	1,415	1,275	254
----------	-------	7,150	[m] 240,500	[m] 222,000	132	13	[n] 1,928	1,860	1,804	126
----------	-------	1,900	91,300	33,100	18	7.5	837.65	816.9	724	113
----------	-------	([j])	([j])	[z] 0	([j])	0	1,095.7	([j])	[r] 843	252
----------	-------	604	[aa] 8,700	[aa] 5,850	24	7	1,435	1,413	[r] 1,119	313
----------	-------	3,320	200,800	186,300	60	10	1,691	1,590	1,543	147
----------	-------	4,290	[m] 180,200	[m] 167,000	106	20	[n] 1,780	1,690	1,612	174.5
----------	-------	40,200	2,567,000	2,281,000	800	72 Clinch 56 Powell	1,034	930	826	194
----------	-------	1,690	49,250	6,564	30	8.9	874	870	812	[s] 60
----------	-------	536	41,160	1,570	([j])	8	1,087.5	1,084.5	[r] 869	[s] 209
----------	-------	595	35,030	1,850	([j])	10	1,276.5	1,273.5	1,087	[s] 187
----------	-------	10,670	1,444,300	1,157,300	248	29	1,710	1,525	1,276	429
----------	-------	2,863	158,250	133,300	85	7.5	1,939.92	1,863.0	[r] 1,275	[s] 597
----------	-------	1,605	138,730	126,000	([j])	4.6	3,012.16	2,881.0	[r] 2,007	[s] 944
----------	-------	1,462	70,810	67,100	([j])	4.5	3,491.75	3,415.0	([dd])	1,200
----------	-------	31,600	1,514,100	1,419,700	555	43.1	1,002	920	873	129
----------	-------	797	9,850	([j])	([j])	([j])	1,245.9	([j])	([j])	68
----------	-------	340	25,280	20,500	([j])	5.5	2,258	2,175	[r] 1,397	861
----------	-------	31,100	1,565,400	1,473,100	463	59	1,075	980	925	149
----------	-------	893	27,100	4,300	36.9	10.3	1,263	1,258	1,195	75
----------	-------	4,520	196,700	150,000	130	17.3 S. Fork Holston. 15.3 Watauga	1,385	1,330	1,264	123
----------	-------	8,750	744,000	625,200	168	24.3	1,742	1,616	1,490	239
----------	-------	72	([j])	327	3	1.75	1,650	1,645	1,585	62
----------	-------	7,200	678,800	627,200	106	16.7	1,975	1,815	1,650	309
----------	-------	2,270	54,500	49,400	120	22	1,950	762	[r] 655	150

[r] At remote powerhouse.
[s] Net head.
[t] Includes capacity of discharge conduits.
[u] Storage projects initially.
[v] Closure date.
[w] Saddle dams and spillway, 1,480 feet additional.
[y] Ocoee No. 1—At high water elevation 834.6. Great Falls—At high water elevation 812.
[z] Reservoir silted.
[aa] 1953 data.
[bb] Saddle dam, 340 feet additional.
[cc] Property of Aluminum Company of America; operation coordinated with TVA system.
[dd] Center line of nozzle elevation 2,284.4.
[ee] Saddle dams, 3,670 feet additional.
[ff] Owned by Carolina Power and Light Co.
[gg] Saddle dams, 1,770 feet additional.
[hh] Surcharged pool for maximum design flood.
[ii] Not in Tennessee Valley.

The demand for electric power in the Tennessee Valley area was being supplied adequately by the hydro plant construction program until 1940 when national defense requirements created an urgent need for additional power. To meet this need, the Congress made successive authorizations of funds on an emergency basis over a period of about 18 months to make more power available in the valley as quickly as possible. In addition to hydroelectric projects these authorizations included the Watts Bar Steam Plant, which started operation early in 1942.

Following World War II, power demands in the area continued to increase. Funds were authorized by the Congress in May 1949 to build Johnsonville Steam Plant as a necessary unit in the normal economy of the area. With the outbreak of hostilities in Korea in June 1950, further congressional action authorized funds successively for six more large steam plants—Widows Creek, Shawnee, Kingston, Colbert, John Sevier, and Gallatin—and all, including Johnsonville, were placed on a high-priority schedule for national defense. Technical Report No. 31, *The Johnsonville Steam Plant*, will be available by the middle of 1959.

TVA's first 25 years

The achievements of TVA during its first 25 years (1933–1958) in carrying out provisions of the act concerning navigation, flood control, and power are briefly summarized in the following paragraphs.

Impoundment of Kentucky Reservoir in August 1944 completed the remaining link of a 650-mile 9-foot-draft navigation channel from Paducah to Knoxville. Ton-mile use of the waterway increased from less than 100 million in 1938 to more than 2 billion ton-miles in 1957.

Regulation of flood flows afforded by the system of dams has enabled TVA to prevent around $140 million in damages since the closure of Norris Dam in 1936. This figure, which is over 75 percent of the total investment in flood control, is the result of system regulation of 24 floods affecting the city of Chattanooga and 34 floods affecting lands along the lower Ohio and Mississippi Rivers. In addition, benefits in the form of increased land values due to greater security from floods to leveed areas on the lower Ohio and Mississippi Rivers are estimated at $150 million.

Power demands in the region served by TVA have far exceeded economical hydro potential. As of June 30, 1958, TVA-installed generating units totaled 122 with a capacity of 8,671,400 kilowatts—2,401,400 kilowatts in 77 hydro units and 6,270,000 kilowatts in 45 steam units. This is more than 10 times the capacity available in 1933—before the creation of TVA—in what is now the area served with TVA power. On that same date the total TVA–ALCOA–Cumberland system included 233 units—147 hydro and 86 steam—with a capacity of 10,222,210 kilowatts—3,727,460 hydro and 6,494,750 steam.

During this 25-year period TVA's engineering and construction forces kept abreast and possibly somewhat ahead of contemporary engineering and construction. They designed, model tested, and are now building the world's highest single-lift lock at Wilson Dam; they planned and installed the world's largest reversible pump-

turbine at Hiwassee Dam; and at Widows Creek Steam Plant they have started construction of an extension in which they will erect the world's largest—also one of its most efficient—steam-electric generating units. A select group of engineers participated in the preliminary design of a nuclear power station. A start has also been made on the use of electronic computers in the solution of complicated engineering mathematical problems.

THE TENNESSEE RIVER SYSTEM

The Tennessee River system has its headwaters in the mountains of eastern Tennessee, western Virginia, western North Carolina, and northern Georgia. Two of the principal tributaries, the Holston and the French Broad Rivers, unite just above Knoxville, Tenn., to form the Tennessee River. Below Knoxville the river flows southwest through the State of Tennessee and is joined by three other principal tributaries, the Little Tennessee and the Hiwassee Rivers from the left and the Clinch River from the right. Beyond Chattanooga the river continues southwesterly into Alabama as far as Guntersville Dam, thence westerly through the Muscle Shoals area in northern Alabama, where the U.S. Corps of Engineers built Wilson Dam during and immediately following World War I. At the northeast corner of Mississippi the river swings north, crosses the State of Tennessee, and continues to Paducah, Ky., where it joins the Ohio River.

Drainage area

Above Paducah the drainage area covers 40,910 square miles; and above Kentucky Dam—near Paducah and lowest dam on the river—it covers 40,200 square miles. It lies mostly in the State of Tennessee, although by no means does it cover the entire state. It also lies partly in the six other States mentioned.

Several headwater tributaries of the Tennessee River have their origin high on the steep slopes of the Blue Ridge and Great Smoky Mountains, where some peaks rise to nearly 7,000 feet and where an abundant growth of hard and soft timber covers the ground. Other headwater streams, notably those of the Clinch and Holston River systems, originate in the Great Valley of the Tennessee where long parallel wooded ridges alternate with scattered woodland and cultivated areas. The western half of the valley is less rugged than the eastern portion, and substantial areas of flat or rolling land occur in middle Tennessee and along the western edge. Approximately 47 percent of the area west of Chattanooga is forested as compared with 56 percent east of Chattanooga.

Profiles of the river system (fig. 2) reveal a river fall from the maximum reservoir surface at Thorpe (formerly Glenville) Dam, highest elevation on the system, to the minimum tailwater surface at Kentucky Dam, lowest elevation on the system, of 3,192 feet in 714.2 river miles. The Tennessee River, commonly referred to herein as the main river, has a fall from the top of the gates at Fort Loudoun Dam to the minimum tailwater at Kentucky Dam of 515 feet in 579.9 river miles.

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Rainfall, runoff, and river flow

Mean annual rainfall over the drainage area (fig. 3) amounts to about 51 inches but varies from year to year from 37 to 63 inches. The heaviest precipitation is over limited mountainous areas along the headwaters of the tributaries where the mean annual reaches 80 to over 90 inches. In portions of the French Broad, Clinch, and Holston Valleys the mean annual is as low as 40 inches.

Mean annual runoff of the Tennessee River in about 42 percent of the precipitation over the drainage area. Although there is some snow in the mountainous areas, there are no glaciers to store the precipitation. Considerable natural storage is afforded, however, by the deep soils and extensive underground storage in many of the tributary areas. This natural storage tends to stabilize the runoff to some extent. The dense ground cover on the steep slopes also helps to check rapid runoff from the heavy rainfall. Heavy storms moving across the Tennessee Valley between December and April become potential causes of widespread major floods in the valley. Between June and October the area is subject to both cyclonic and local storms and to intense rains accompanying the passage of decadent hurricanes. Protection against damage by such floods was one of the principal reasons for building the dams; and in the design and operation of the dams and reservoirs, flood control is one of the primary purposes.

Natural river flow at the site of Kentucky Dam ranged from a minimum of 4,500 cubic feet per second in 1925 to a maximum of 500,000 cubic feet per second in 1897, with an average of 63,600 from 1889 to 1956. At the Fort Loudoun damsite it varied from 1,600 cubic feet per second in 1925 to 300,000 cubic feet per second in 1867, with an average of 13,500 cubic feet per second from 1899 to 1955.

The topographic and hydrologic features of the valley area combine to make the multiple-purpose water control development, including the generation of hydroelectric power, in the Tennessee River Basin both feasible and economical.

THE POWER SYSTEM

TVA is the sole supplier of electric power for an area of about 80,000 square miles in which some 5 million people live and work. TVA has been the sole supplier since, under the authorization of Congress, it joined with municipal and cooperative systems in the area to purchase existing privately owned power facilities. In meeting the responsibility that every power system has to the area it serves, TVA must plan and build ahead so that power supply will keep pace with growing power needs.

In 1933, the installed capacity in the area now served by TVA power was approximately 800,000 kilowatts with a yearly generation of some 1½ billion kilowatt hours. At the end of fiscal year 1958 on June 30, 1958, twenty-five years later, the installed nameplate capacity of the TVA system was 10,222,210 kilowatts, and the generation during that fiscal year was 60.8 billion kilowatt hours—19.3 billion in the hydro plants and 41.5 billion in the steam plants. The hydro generation that year was greater than for any previous 12 con-

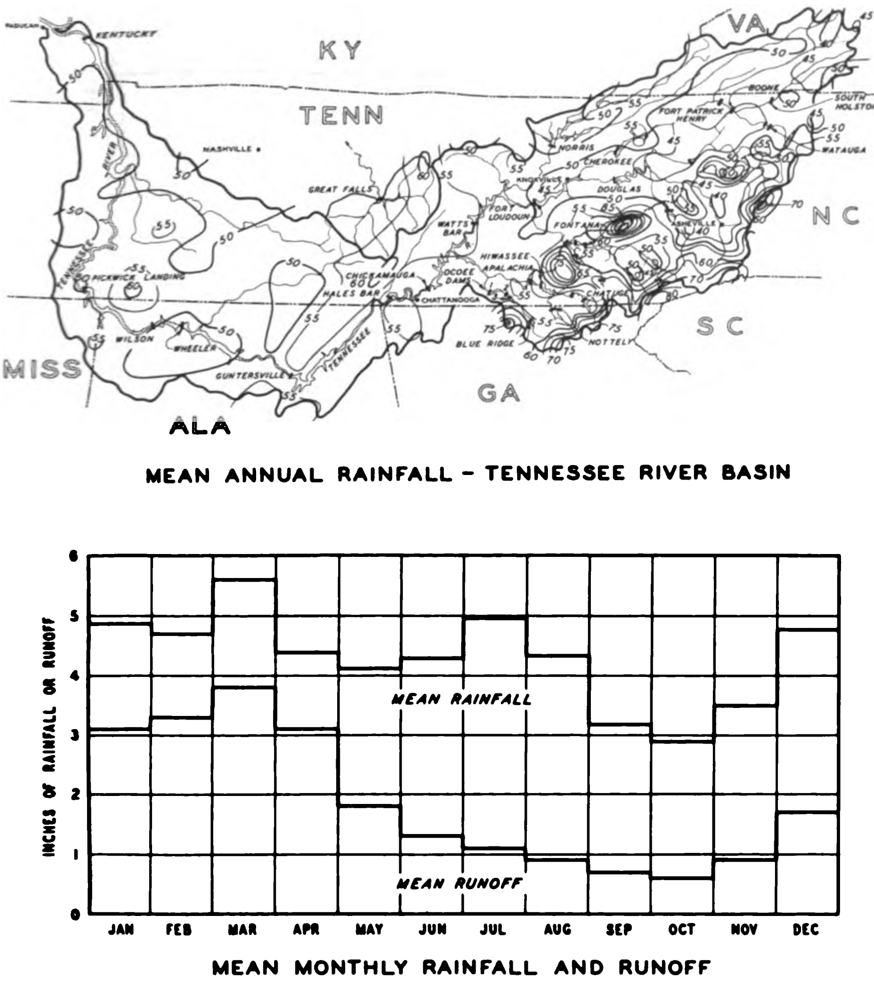


FIGURE 3.—*Rainfall and runoff—Tennessee River Basin.*

secutive months in TVA's history due to the unusually favorable rainfall in terms of both amount and its distribution. Additional capacity under construction and proposed as of September 1958 is scheduled to increase the total nameplate capacity to nearly 12 million kilowatts in 1960. This total scheduled capacity figure includes 595,000 kilowatts in hydro plants owned by the U.S. Corps of Engineers on the Cumberland River, and 425,960 kilowatts in hydro plants owned by the Aluminum Co. of America on various tributary rivers in the Great Smoky Mountains area. These latter plants are integrated into the TVA system and the power is dispatched by TVA. All steam power is supplied from TVA plants. Figure 4 shows the TVA power system as of June 1958 and figure 5 shows the installed capacities and peak loads of the system from 1934 to the latter part of 1958.

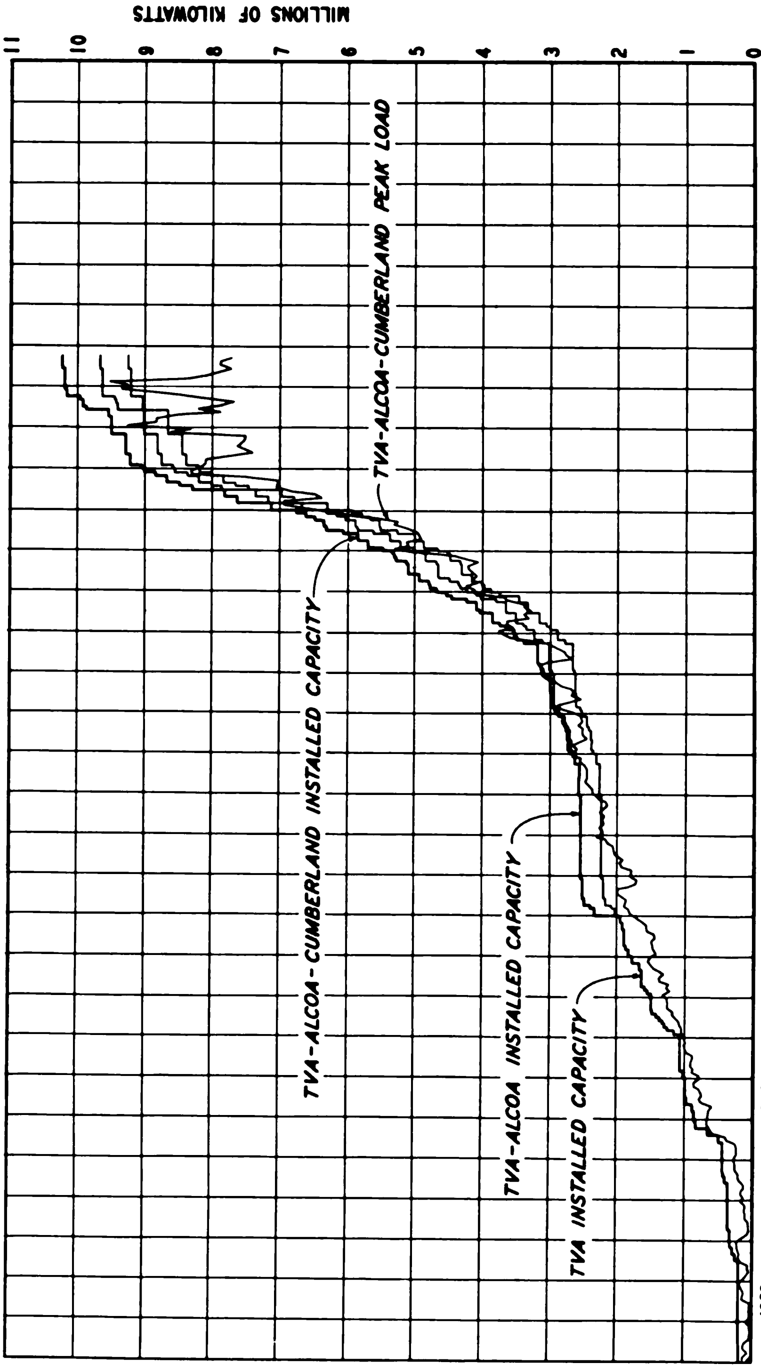
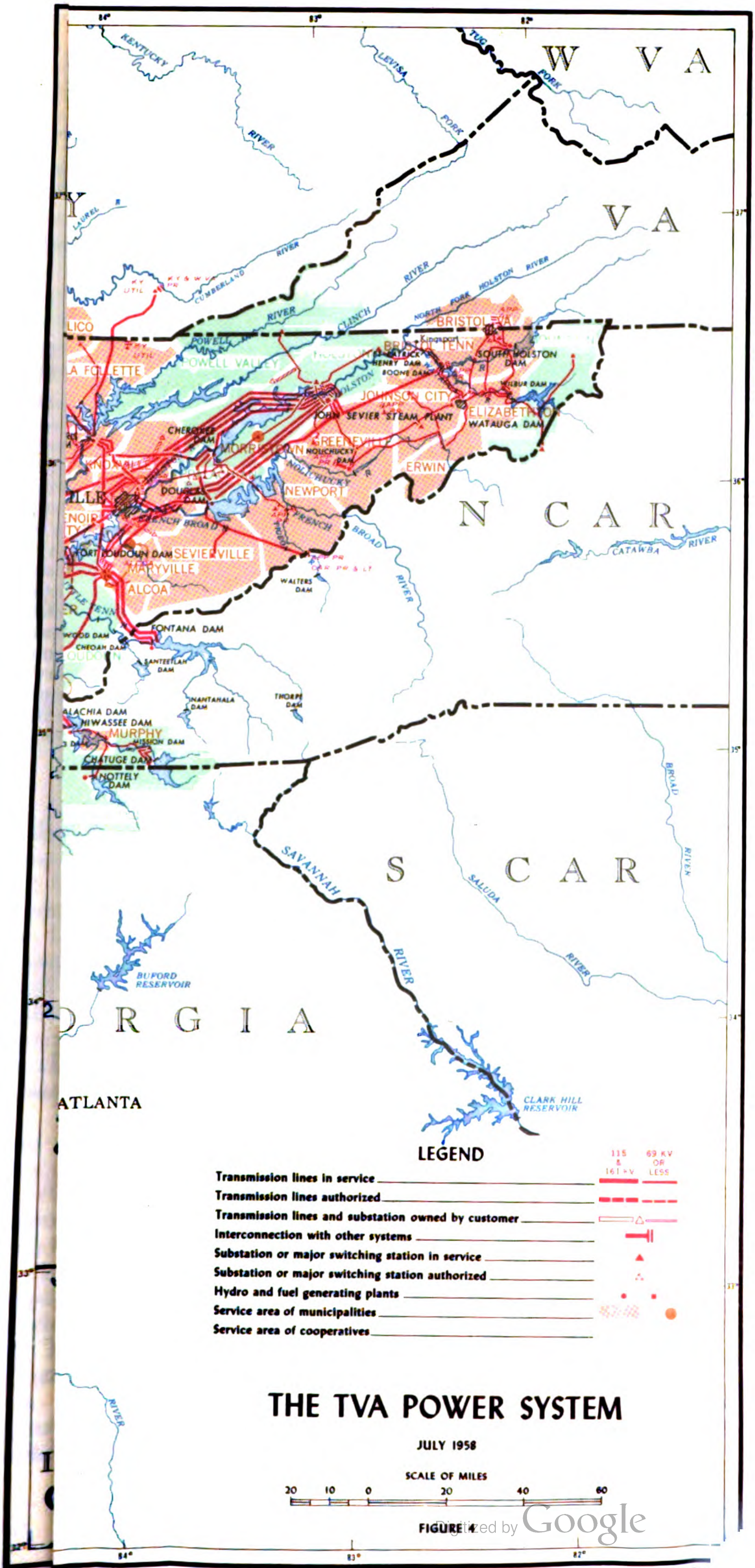


FIGURE 5.—*Installed capacity and peak load—TVA power system.*


W VA
VA
N CAR
S CAR
GEORGIA
ATLANTA
BRISTOL VA
BRISTOL TENN
Kingsport
SOUTH HOLSTON DAM
WILBUR DAM
JOHNSON CITY
ELIZABETHTON
WATAUGA DAM
JOHN SEVIER STEAM PLANT
CHEROKEE DAM
MORRISTOWN
GREENEVILLE
ERWIN
NEWPORT
DOUGLAS DAM
SEVIERVILLE
FORT LOUDOUN DAM
MARYVILLE
ALCOA
FONTANA DAM
CHEOAH DAM
SANTEETLAH DAM
NANTAHALA DAM
THORPE DAM
WALTERS DAM
HIWASSEE DAM
MURPHY
MISSION DAM
CHATUGE DAM
NOTTELY DAM
LA FOLLETTE
POWELL VALLEY
BUFORD RESERVOIR
CLARK HILL RESERVOIR
CUMBERLAND RIVER
CLINCH RIVER
HOLSTON RIVER
FRENCH BROAD RIVER
CATAWBA RIVER
SAVANNAH RIVER
SALUDA RIVER
BROAD RIVER
LEGEND
115 & 161 KV
69 KV OR LESS
Transmission lines in service
Transmission lines authorized
Transmission lines and substation owned by customer
Interconnection with other systems
Substation or major switching station in service
Substation or major switching station authorized
Hydro and fuel generating plants
Service area of municipalities
Service area of cooperatives
THE TVA POWER SYSTEM
JULY 1958
SCALE OF MILES
20 10 0 20 40 60
FIGURE 4

PROJECT CONCEPTION

In the TVA engineering organization the conception of a project as to feasibility and scope is a function of TVA's Division of Water Control Planning. This function may be expressed as including the engineering which is necessary as a basis for authorization and appropriation. It involves studies of a number of phases which are made mainly in appropriate branches of the planning division. The design division is consulted on significant questions.

The various phases studied by the Division of Water Control Planning prior to making a recommendation as to the feasibility of a project are:

1. *Flood control.*—The extent to which flood control reservation should be included in each project.
2. *Navigation requirements.*—Need for and general features of navigation facilities are determined in cooperation with the Division of Navigation and Local Flood Relations.
3. *Power.*—The power potential of the site. This includes determination of the present and ultimate installed capacity, number and size of units, dependable capacity, and outputs under different operating conditions.
4. *Health and safety requirements.*—Control of malaria in the reservoirs is linked closely with proper control of lake levels in the marginal areas.
5. *Site.*—Consideration of topographic, hydrologic, and geologic features.
6. *Reservoir levels.*—Appraisal of features affected by the proposed reservoir, and an evaluation of benefits and costs between different levels.
7. *Preliminary layout and estimates.*—A preliminary layout is made for the project, and quantity and cost estimates prepared for use in seeking authorization and appropriation of funds to begin construction.
8. *Economics.*—Determination of annual costs and annual benefits.

PROJECT DESIGN

After the initial appropriation for a project has been authorized on the basis of the planning studies outlined in the preceding discussion, it becomes the function of the Division of Design to prepare construction plans and specifications and supply all necessary information to the purchasing and construction organizations. The tentative layout prepared as a basis for the initial appropriation request is reviewed and changed if it proves advantageous to do so. After such revision it becomes the basis of the detailed plans. In the preparation of these plans, contacts must be maintained with numerous other divisions or organizations of the TVA. The most important of these are discussed briefly in the following paragraphs.

Division of Construction.—Contact must be maintained with this division in several respects. In the first place, the exploration which had been done as preliminary to the initial appropriation request for the project is generally insufficient for the complete design of the structures. Much additional information must be obtained by means of drilling, seepage tests, etc. The Division of Construction now is required to furnish such information as is necessary to complete the design. An effort has constantly been made during the history of TVA to utilize to as great an extent as possible existing construction plant when new projects are developed. This utilization has a very considerable bearing on types of structures to be built and upon the dimensions thereof. This relationship is close and important.

Division of Navigation and Local Flood Relations.—Those in this division concerned with the improvements and extension of navigation consult with the design division upon such questions as navigable depths of channel and as to the scope, capacity, and appurtenances of river terminals handled by TVA.

Division of Reservoir Properties.—The site planning staff of this division is concerned with the relation of the completed projects to the public and is interested in matters of access, public recreation, and similar matters. In this regard it is interested in the finished appearance of the projects, including landscaping. All these questions enter into the details of the project layout, and much consultation is required in this field.

Divisions of Power.—The divisions of power, which take over and operate the completed dams and powerhouses,[2] are consulted as to questions of powerhouse layout and as to matters which affect operating convenience and cost.

Materials Testing Laboratory.—In addition to field laboratories at active construction projects, the Division of Construction has maintained a separate materials testing laboratory at Knoxville for the purpose of special testing of soils, concrete, aggregates, cement, paint, ceramics, asphalt, steel, and other items pertinent to TVA's structures. The Division of Design has made full use of this laboratory in developing many specifications for materials and their use.

Hydraulic Laboratory.—A particularly close relationship exists between the Division of Design and the Hydraulic Laboratory, which is organized and administered as a section of the Division of Water Control Planning. The design of many structures is fixed in the laboratory as far as hydraulic performance of the structure is concerned. While the type of structure is determined in the design office, the dimensions must in many cases be fixed in the laboratory. Cooperation here is very important and has been highly effective.

U.S. Corps of Engineers.—Inasmuch as all locks on the Tennessee River are operated and maintained under the authority of the U.S. Corps of Engineers, that organization is concerned with all matters affecting operating convenience and cost. The importance of this relationship has been so great that most of the locks built by TVA have actually been designed by the Corps of Engineers. However, the lock at Kentucky Dam and the lock now under construction at Wilson Dam were designed by TVA, but with the benefit of advice from the Corps of Engineers upon questions relating to operation.

ORGANIZATION OF THE DIVISION OF DESIGN

Personnel of the early TVA design organization was recruited in 1933 and in the several following years at a time when engineering and construction were at a low ebb throughout the country, and

[2] The operation and maintenance of plant facilities is a function of the Divisions of Power. However, the responsibility for control of the river—reservoir levels, water releases, and storage—is vested in the Chief Engineer and Chief Water Control Planning Engineer.

when a considerable amount of capable engineering talent was available. The TVA's personnel policy requires selection on the basis of merit alone,[3] free of political influence. As a result of the market and this policy possibly more than any other factors, a group of able, seasoned engineers with especially favorable backgrounds of training and experience was assembled from all parts of the country. The organizational environment was excellent. The management insisted on the highest standards of performance but gave to its responsible personnel unusually wide latitude for independent action. Under these conditions a spirit of individual responsibility and of close cooperation quickly developed which has characterized the entire organization.

The work of TVA in the design of its projects began with a small staff of engineers assembled soon after passage of the TVA Act in May 1933. In order to expedite construction, TVA, lacking time to develop a design organization of its own, requested that designs for its first two projects, Norris and Wheeler Dams, be developed by the U.S. Bureau of Reclamation.

Construction of Norris and Wheeler Dams began in October and November 1933, respectively, with drawings supplied by the Bureau of Reclamation and reviewed by TVA. After the TVA Division of Design was organized and sufficiently staffed, some of the remaining items of design on these two projects were gradually taken over.

Pickwick Landing Dam, third to be built by TVA, was the first to be designed entirely by the TVA design organization. The design was started in November 1934 and field construction was begun in March 1935. Then came Guntersville, Chickamauga, and Hiwassee within the next 17 months so that before the first unit at Norris was on the line five other stations were under design and construction. Later, under the pressure of national defense and World War II, the production ability of the design division was put to a crucial test. Between April 1940 and April 1945 a total generating capacity of 985,800 kilowatts in 26 new units was designed, built, and placed in commercial operation. This included 9 new hydro projects with 15 units, 1 new steam plant with 4 units (Watts Bar), and 3 existing hydro plants extended to add 7 new units. The Chatuge and Nottely Dams were also completed during the period although power facilities were not added until several years later.

For the first plants designed by the TVA, a technical staff consisting of specialists in each of the branches of engineering involved was appointed under the Chief Design Engineer. These branches were: Architectural, Civil, Structural, Mechanical, Electrical, Materials and Inspection and Testing, and Highway and Railroads. A Drafting Service Branch was also organized. Each project was assigned its own design production group handling the several branches of engineering such as electrical, mechanical, etc. In July 1939 this organization was changed to keep the staff engineers, but to continue all the design production for all projects under one group. For example, the chief of the mechanical design group was in charge of mechanical design for all projects. This latter organization greatly facilitated designs, procurements, etc., because expe-

[3] Case, H. L., "Cornerstones of Personnel Administration in TVA." *Personnel Administration*, 11:10–12, January 1949.

rience gained in one project could be used to the benefit of later projects when they were handled by the same group of engineers. Standardizations resulted which greatly increased the engineering capacity of the design organization. This was dramatically exemplified later when during the years 1950–55 a relatively small group of engineers designed seven large steam plants with a total capability of approximately 6,500,000 kilowatts. Figure 6 shows the organization chart of the Division of Design as of January 1, 1956.

ORGANIZATION OF THE MECHANICAL DESIGN BRANCH

The organization chart of the Mechanical Design Branch as of January 1, 1956, is shown in figure 7.

All responsibility for the mechanical design of power facilities for the TVA is vested in the Mechanical Design Branch, headed by the Head Mechanical Engineer. This includes steam as well as hydro plants. However, as in any other large engineering organization, this responsibility is shared with the rest of the members of the branch in order that maximum efficiency and performance may be maintained. The hydro work of the branch is divided into four sections, each headed by an engineer who is an expert in his field and who reports to the Head Mechanical Engineer. These sections are: hydroelectric turbines, hydroelectric machinery and piping, heating, ventilating and air conditioning, and procurement and production. Experts are always necessary to carry on power plant engineering work, which involves an extensive range of interests. An individual may in some cases prefer to broaden his interests and activities by generalizing over a broad field, but without a specialist heading each special field of work it would be impossible to achieve the optimum of design and performance. Specialists were developed, therefore, from the beginning, and no one was expected to be an authority on all phases of the work.

Each section head is trained to become TVA's authority in his particular field. He handles all engineering contacts with manufacturers' representatives and visits the factories, as necessary, to inform himself regarding the latest manufacturing practices and advanced thinking. He writes the purchase specifications, analyzes the bids, recommends the awards, assists with the technical interpretation of purchase contacts, follows production schedules of equipment in manufacture, watches progress charts of field erection, and participates in field testing.

In addition, he supervises a group of designers to which is assigned his particular field of hydro plant engineering. He is given opportunities to visit and examine generating stations already completed, to follow and inspect new stations under construction, to discuss station construction with the TVA's construction division and operation with the TVA's operating division, and is expected to become the center of information on his specialty. This group prepares construction drawings and construction specifications, bills all items of equipment and materials to be purchased, and writes instructions for operating the station.

Standards are developed both for purchase specifications and for construction details, but the standards are sufficiently flexible to allow construction originality for specific conditions at each project.

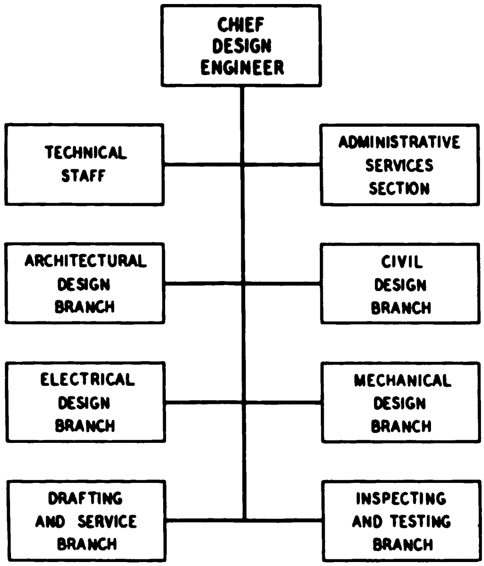


FIGURE 6.—*Organization chart—Division of Design—1956.*

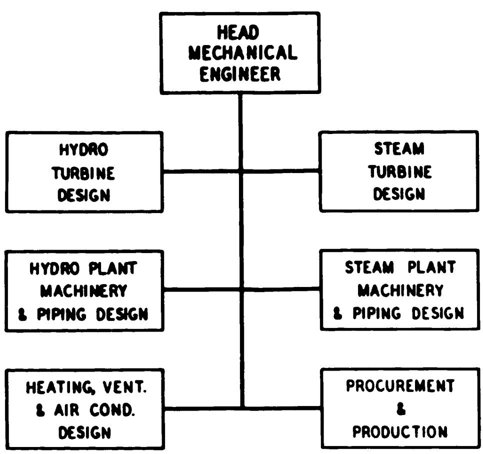


FIGURE 7.—*Organization chart—Mechanical Design Branch—1956.*

Supervisory assistants schedule the work in coordination with construction schedules and promote adherence to established schedules.

Having carefully selected the personnel on the basis of merit alone, the individual's capacities and special qualifications are used to the fullest extent. The lines of organization were made sufficiently flexible to promote individual initiative and to encourage individual responsibility.

SCOPE OF REPORT

This report has 18 chapters and 6 appendixes and is illustrated with figures and plates. The figures include both photos and line drawings, the latter having been especially prepared for illustration purposes. The plates are reductions of complete drawings and each covers two facing pages which appear in the text near the page on which the plate is first referred to. Because of the complexity of the mechanical systems described, these complete drawings (plates) were necessary for illustrative purposes.

Chapter 1.—This introductory chapter first presents background information concerning TVA and its water control and power systems, and summarizes its 25-year engineering and construction achievements. The phases of engineering entering into project conception are then itemized, and the principal organizations with which project design must be coordinated are discussed briefly. Toward the end of the chapter are concise descriptions of the organizations of the Division of Design and its Mechanical Design Branch—the 25-year history of the division is included in these descriptions.

Chapter 2.—Entitled "The Projects" this chapter first classifies TVA's hydro projects into three general types. Separate discussions then follow—in chronological order by date of first generation—of each of the 20 TVA-built projects and the 3 acquired in which TVA installed additional generating units. Each project discussion gives the location, chronology, cost, and arrangement of the particular project followed by descriptions of the major mechanical equipment and auxiliary service systems. At the end of the chapter are descriptions of the six other acquired projects.

Chapters 3 and 4.—The factors concerning the design, selection, and erection of hydraulic turbines and governors are discussed in chapter 3, "Hydraulic Turbines," and chapter 4, "Governors for Hydraulic Turbines." At the end of chapter 3 is a section covering turbine inlet valves as installed in the penstocks of four TVA-built projects.

Chapter 5.—During the early years of TVA, when system plants and interconnecting ties were much fewer than exist today, auxiliary gasoline-engine-driven generator units were installed in 11 of the hydro plants. They were sources of emergency power for operation of essential plant auxiliaries in the event of simultaneous loss of all station generation and transmission facilities. These installations are covered in this chapter, "Auxiliary Power Generators."

Chapter 6.—Chapter 6, "Elevators," discusses the requirements for the elevators provided at 13 hydro projects.

Chapters 7 through 12.—The features of design observed in the layout of the principal service systems of the hydro plants comprise the discussions of chapters 7 through 12: "Compressed Air Systems," "Raw Water Systems," "Treated Water Systems," "Oil Systems and Handling," "Drainage, Unwatering, and Filling Systems," and "Sanitary Systems."

Chapter 13.—In this chapter, "Fire Protection," measures taken for controlling fire hazards are described and the development of various fire protection systems is explained.

Chapter 14.—"Heating, Ventilating, and Air Conditioning" is the title of this chapter which explains the design of the systems required for these purposes, and presents reasons governing the selection of necessary equipment and materials.

Chapter 15.—All normal maintenance repair work required at a hydro plant is done in a machine shop within the plant. Major repairs are made in the central repair shops of the system at Wilson Dam Reservations. Chapter 15, "Machine Shops," discusses the equipment and space requirements of the machine shops at TVA's hydro plants and at its central repair shops.

Chapter 16.—This chapter, "Piping Design," outlines some of the more important requirements and essentials for designing hydraulic plant piping systems.

Chapter 17.—The mechanical design features of the more important miscellaneous structures and projects required as a part of the overall TVA program—backwater protection, malaria control, construction camps and villages, public facilities, and a variety of other structures—are covered in this chapter, "Miscellaneous Structures and Projects."

Chapter 18.—Whereas chapter 1 presented outlines of the Division of Design and the Mechanical Design Branch organizations, chapter 18, "Schedules and Design Procedures," is devoted to the operating requirements of the Mechanical Design Branch including the coordination of designs, drawings, schedules, and procedures to insure integrated and harmonious designs and efficient performance.

Appendixes A through E.—Appendix A contains selected information pertaining to TVA's installations of hydraulic turbines, governors, turbine inlet valves, and hydro generating units, including a typical Invitation to Bid and representative specifications and turbine test data. Appendixes B and C comprise typical specifications for auxiliary equipment, and for heating, ventilating, and air-conditioning equipment. Appendix D is a compilation of typical construction specifications for the guidance of field forces in installing mechanical equipment or applying materials. Appendix E includes a few typical operating instructions prepared by the Mechanical Design Branch for each project.

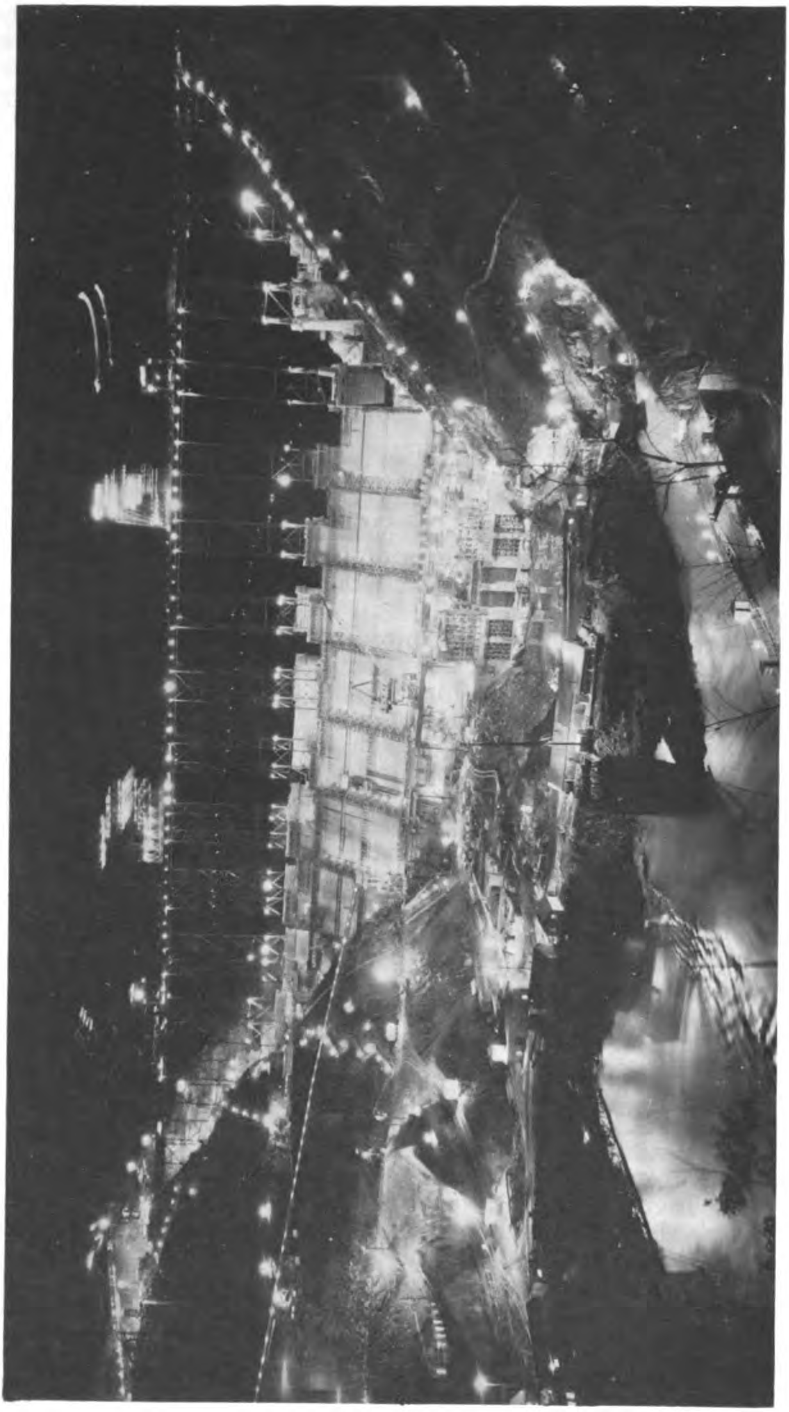


FIGURE 8.—*Construction at night—Fontana Dam.*

Chapter 2

THE PROJECTS

At the present time (1958) there are 49 hydro projects in the TVA system, 29 owned by TVA, 15 by the Aluminum Co. of America (ALCOA), and 5 by the Corps of Engineers, U.S. Army. Not included in the preceding figures are 9 small hydro plants acquired by TVA during its early years and subsequently retired from service.

This chapter describes in detail the 23 projects that are essentially those designed and built by TVA. Exceptions are made in the case of three acquired plants, however, to include units added by TVA. This was done so that the scope of TVA hydro station design during its first 25 years would be specifically covered. Norris and Wheeler with its first 2 units are also included, although the original design and drawings for the dams and power plants (exclusive of the switchyards) were prepared by the U.S. Bureau of Reclamation since the TVA design organization was not sufficiently assembled to handle this work at that time. The 6 other of the 29 TVA-owned projects were all acquired and no additional units have been installed in them. They are described briefly near the end of the chapter followed by short sections naming the 9 retired hydro plants and the remaining 20—owned by ALCOA and the Corps of Engineers—in the system.

Table 2 lists the 23 projects together with pertinent data which determined their ratings and general types and arrangements. They are listed in the chronological sequence in which they went into commercial operation, and trends in design therefore reflect in some respects the development of the TVA design policy. Figure 8 shows Fontana Dam—TVA's highest—under construction at night during World War II.

In the following pages of this chapter the projects are first classified by type. Then, for each project, the location, chronology, cost, and arrangement are given followed by brief descriptions of the major mechanical equipment and auxiliary service systems. Ensuing chapters cover these items in more detail and present the basic design reasoning and factors governing the selection of equipment and systems.

The location of the site, the number and capacity of the generating units, and the general type of the project were determined by studies of natural conditions over the entire river system by the Division of Water Control Planning.

TABLE 2.—*TVA generating station basic data (stations are listed in sequence of initial commercial operation)*

Station	Construction started	First commercial operation	Project type	Useful controlled storage, acre-feet	Average unregulated flow, cubic feet per second	Rated head, feet	Turbine, horsepower	Turbine type	Unit revolutions per minute	Number of units	Generator	
											Kilovolt-amperes	Kilowatts nameplate
Norris	Oct. 1, 1933	July 28, 1936	Tributary	2,281,000	4,100	165	66,000	Francis	112.5	2	56,000	50,400
Wheeler	Nov. 21, 1933	Nov. 9, 1936	Main river	347,500	49,000	48	45,000	Propeller	85.7	8	36,000	32,400
Pickwick	Mar. 8, 1935	June 29, 1938	do	418,400	54,000	43	48,000	Kaplan	81.8	6	40,000	36,000
Guntersville	Dec. 4, 1935	Aug. 1, 1939	do	162,900	42,000	36	34,000	do	69.2	4	27,000	24,300
Chickamauga	Jan. 13, 1936	Mar. 4, 1940	do	329,400	36,500	36	36,000	do	75.0	4	30,000	27,000
Hiwassee:												
Unit 1	July 15, 1936	May 21, 1940	Tributary	364,700	1,900	190	80,000	Francis	120.0	1	64,000	57,600
Unit 2 [1]	Jan. 4, 1954	May 24, 1956				190	80,000	do	105.9	1	70,000	59,500
Watts Bar	July 1, 1939	Feb. 11, 1942	Main river	377,600	26,400	52	42,000	Kaplan	94.7	5	33,333	30,000
Wilson Units 9–18	Sept. 30, 1940	Mar. 25, 1942	Tributary [2]	52,500	50,500	92	35,000	Francis	100.0	10	28,000	25,200
Cherokee	Aug. 1, 1940	Apr. 16, 1942	Tributary	1,473,100	4,600	100	41,500	do	94.7	4	33,333	30,000
Douglas:												
Units 1 & 3	Feb. 2, 1942	Mar. 21, 1943	Tributary	1,419,700	6,700	100	41,500	do	94.7	2	33,333	30,000
Units 2 & 4	Sept. 11, 1946	May 22, 1949				80	35,500	do	90.0	2	28,888	26,000
Ocoee No. 3	July 17, 1941	Apr. 30, 1943	Diversion	5,850	1,150	280	33,500	do	200.0	1	30,000	27,000
Apalachia	do	Sept. 22, 1943	do	[3] 8,700	2,000	360	53,000	do	225.0	2	40,000	37,500
Fort Loudoun	July 8, 1940	Nov. 9, 1943	Main river	109,300	13,800	65	44,000	Kaplan	105.8	4	35,555	32,000
Kentucky	July 1, 1938	Sept. 14, 1944	do	4,010,800	65,000	48	44,000	do	78.3	5	35,000	32,000
Fontana	Jan. 1, 1942	Jan. 20, 1945	Tributary	1,157,300	3,700	330	91,500	Francis	150.0	3	75,000	67,500
Watauga	Feb. 16, 1942	Aug. 30, 1949	Diversion	627,200	719	216	34,500	do	200.0	2	27,777	25,000
Wilbur Unit 4	Sept. 21, 1948	July 19, 1950	Main river [4]	327	730	58	9,700	Propeller	180.0	1	7,777	7,000
South Holston	Feb. 16, 1942	Feb. 13, 1951	Diversion	625,200	1,020	180	48,500	Francis	144.0	1	38,888	35,000
Hales Bar Units 15 & 16	Aug. 1, 1949	July 11, 1952	Main river	12,370	38,000	36	34,000	Kaplan	69.2	2	27,000	24,300
Boone	Aug. 29, 1950	Mar. 16, 1953	Tributary	150,000	2,500	90	34,500	Francis	100.0	3	31,250	25,000
Fort Patrick Henry	May 14, 1951	Dec. 5, 1953	Main river [4]	4,300	2,590	61	25,000	Kaplan	138.5	2	20,000	18,000
Chatuge	July 17, 1941	Dec. 9, 1954	Diversion	229,300	475	100	13,800	Francis	180.0	1	11,111	10,000
Nottely	do	Jan. 10, 1956	do	171,200	410	124	21,000	do	180.0	1	16,667	15,000

[1] Hiwassee Unit 2 pump-turbine is reversible and as a centrifugal pump is rated 205-foot head, 102,000 horsepower, 3,900 cubic feet per second, 105.9 revolutions per minute, with a motor rated 102,000 horsepower.

[2] Although Wilson Dam is located on the main river, it is classified as a tributary type because of the high head.

[3] Volume for operation of Hiwassee Unit 2 pump-turbine.

[4] Although Wilbur and Fort Patrick Henry Dams are located on tributaries, they are classified as main-river types because of the low head and structural features.

PROJECT CLASSIFICATION BY TYPE

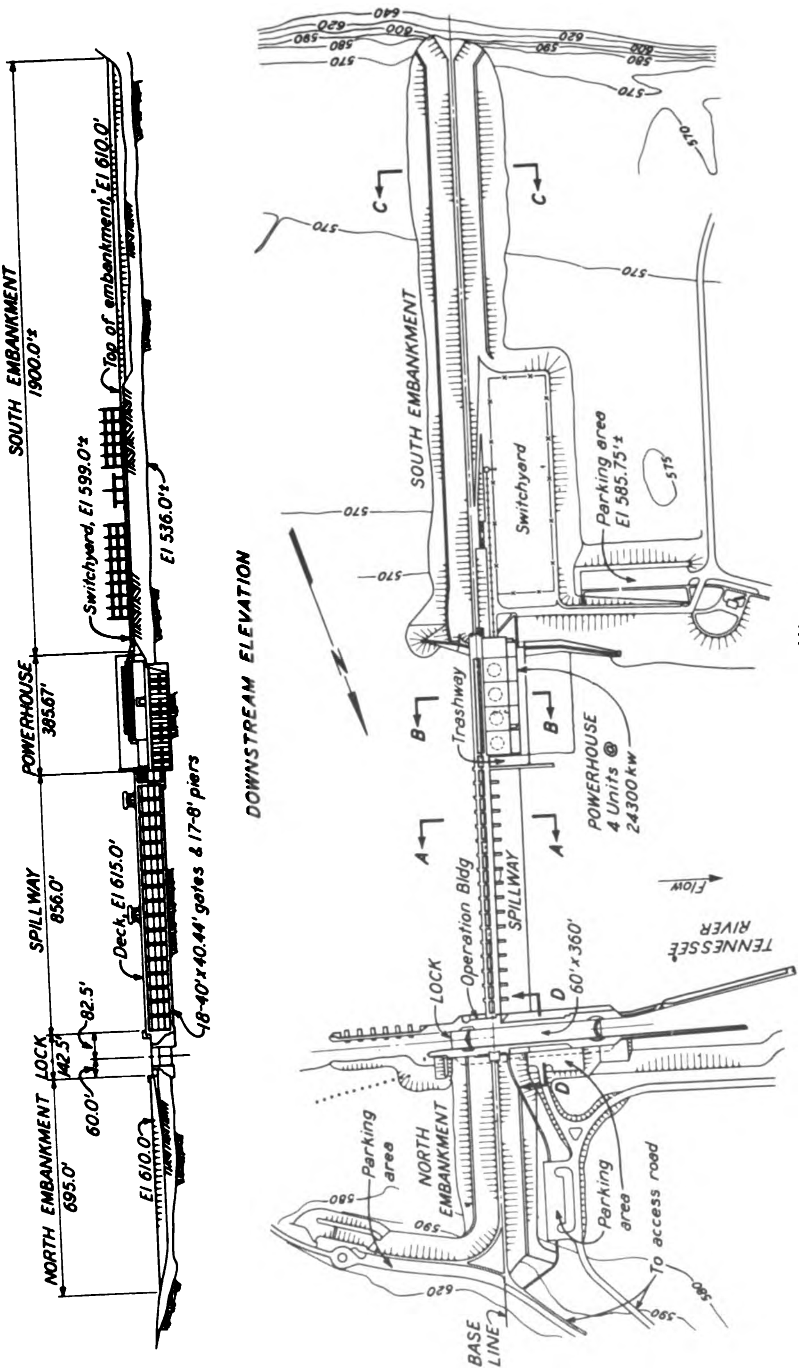
All TVA hydro projects fall into three general types:

1. Main-River type, with a low dam and with the powerhouse built into the dam, and usually with a navigation lock.
2. Tributary type, with a high dam and with the powerhouse close to its base.
3. Diversion type, with a small diversion dam and conduit leading to a remote powerhouse.

The main-river type (fig. 9) was indicated for Wheeler, Pickwick, Guntersville, Chickamauga, Watts Bar, Fort Loudoun, Kentucky, Hales Bar, all located on the main river, and for Wilbur and Fort Patrick Henry, which, although located on tributaries, are classified as main-river type because of their low head. The river at most of these sites was comparatively wide and shallow. The structures include earth embankments in most cases, gravity type concrete dams, broad spillways, short intakes to several generating units, and, except at Wilbur and Fort Patrick Henry, navigation locks. The rated heads range from 36 to 65 feet. All these stations have adjustable blade, low speed Kaplan turbines, except Wheeler and Wilbur, which, because of their small variation in head use fixed blade propeller type turbines. At Hales Bar 2 additional units were added to the original 14 purchased from Tennessee Electric Power Co. This was done by extending the powerhouse over the spillway section of the dam. At Wilbur 1 additional unit was added to the original 3 purchased from East Tennessee Electric Co. by extending the powerhouse over the dam in the same manner.

The tributary type (fig. 10) was indicated for Norris, Hiwassee, Cherokee, Douglas, Fontana, Boone, Chatuge, and Nottely, all on tributaries, and for Wilson, which, although on the main river, fits into this classification by virtue of its relatively high head. The river at each site was narrow, except at Wilson, and the banks were steep. The structures include gravity type dams with spillways, longer intakes, and except at Wilson there are fewer generating units than at the main-river plants. Navigation locks were not required except at Wilson. Rated heads range from 90 to 330 feet; and Francis type medium-speed turbines were used. The powerhouse was built close to the toe of the dam, but was not made a part of the dam as was the case with most of the main-river dams.

The diversion type (fig. 11) was indicated for Ocoee No. 3 and Apalachia with Watauga and South Holston—although both are high dams—arbitrarily included in this class because in each case the powerhouse is detached from the dam. The terrain was rough, and the river was narrow. The structures in each case include a dam, a tunnel or power conduit, a surge tank, and penstocks to only one or two generating units. Navigation locks were not required. Rated heads range from 180 to 360 feet, and Francis-type medium-speed turbines were used. The powerhouse was separated from the dam a distance ranging from a few feet to several miles.


SOUTH EMBANKMENT
1900.0'±
POWERHOUSE
385.67'
SPILLWAY
856.0'
LOCK
142.5'
NORTH EMBANKMENT
695.0'
Top of embankment, El 610.0'
Switchyard, El 599.0'±
El 536.0'±
Deck, El 615.0'
18-40'x40.44' gates & 17-8' piers
82.5'
60.0'
El 610.0'
DOWNSTREAM ELEVATION
SOUTH EMBANKMENT
Switchyard
Parking area
El 585.75'±
Trashway
POWERHOUSE
4 Units @
24300 kw
Operation Bldg
SPILLWAY
LOCK
60'x360'
Flow
TENNESSEE
RIVER
NORTH
EMBANKMENT
Parking
area
To access road
BASE
LINE
PLAN

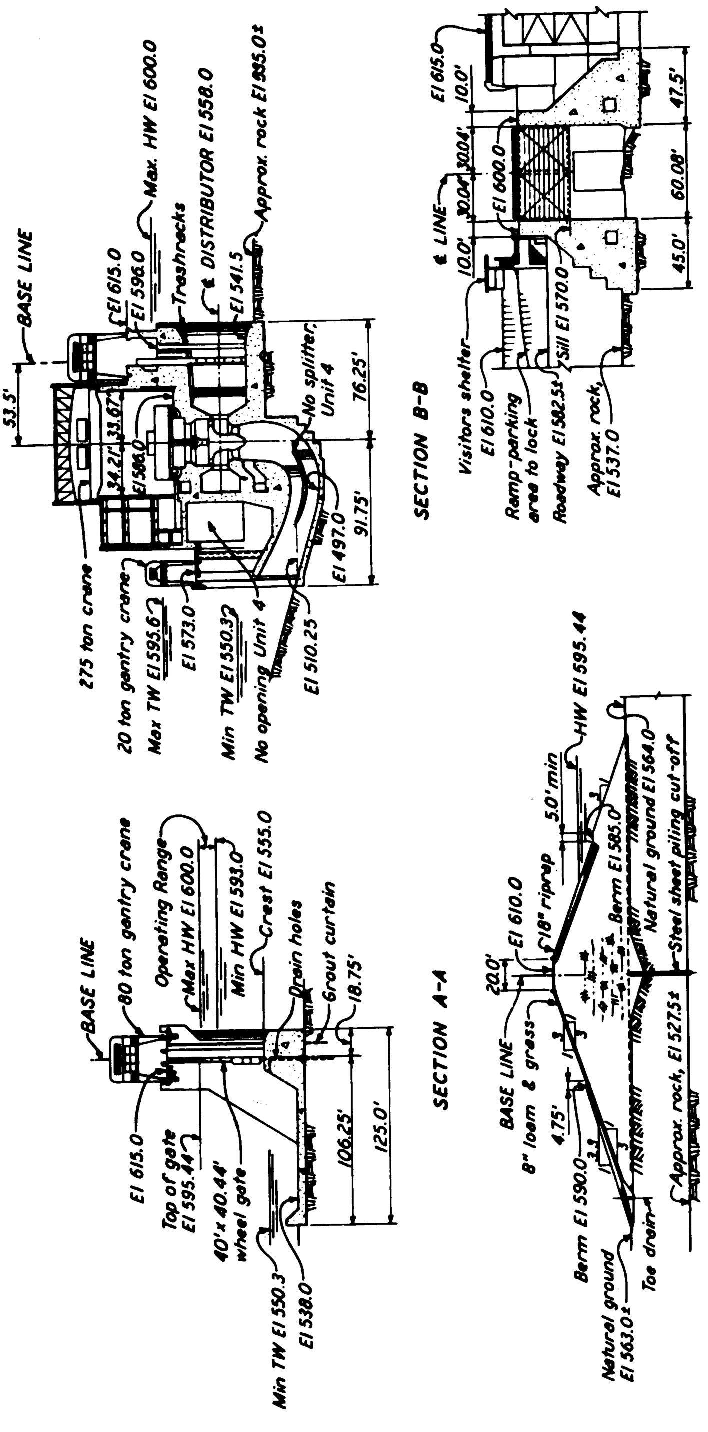


FIGURE 9.—*Typical main-river project—Guntersville—plan, elevation, and sections.*

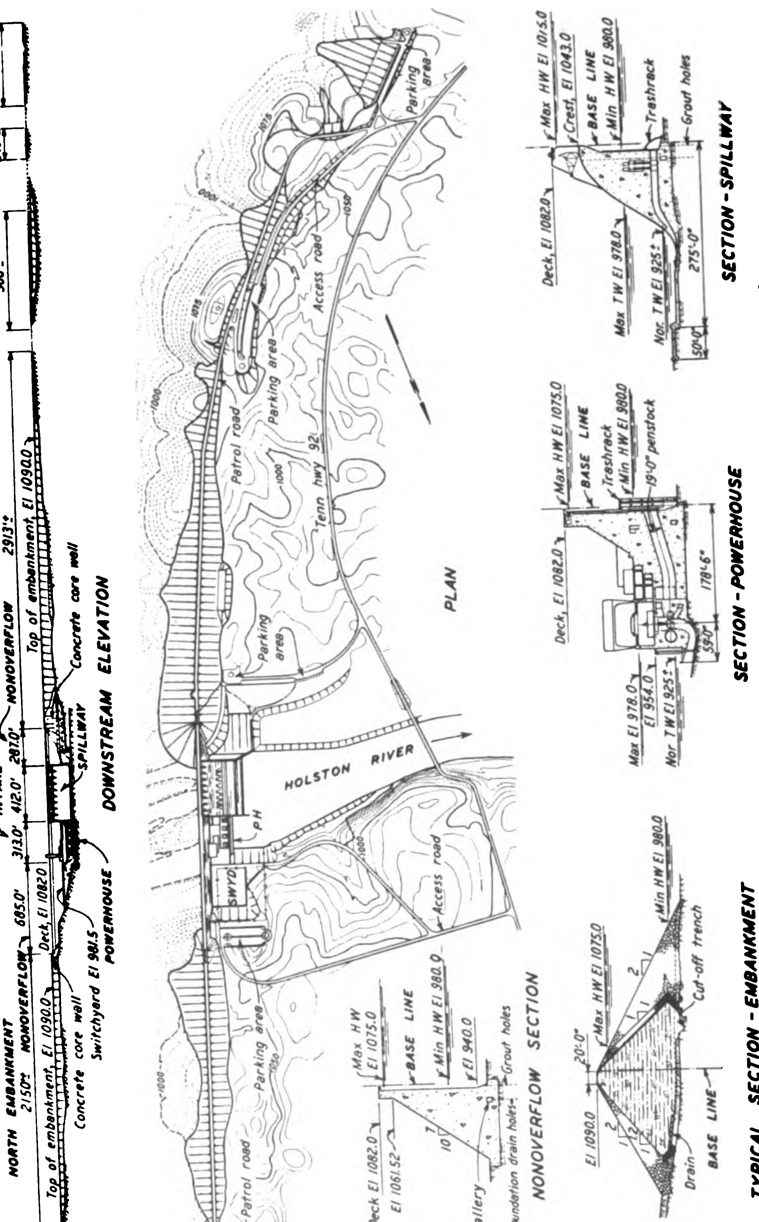


FIGURE 10.—Typical tributary project—Cherokee—plan, elevation, and sections.

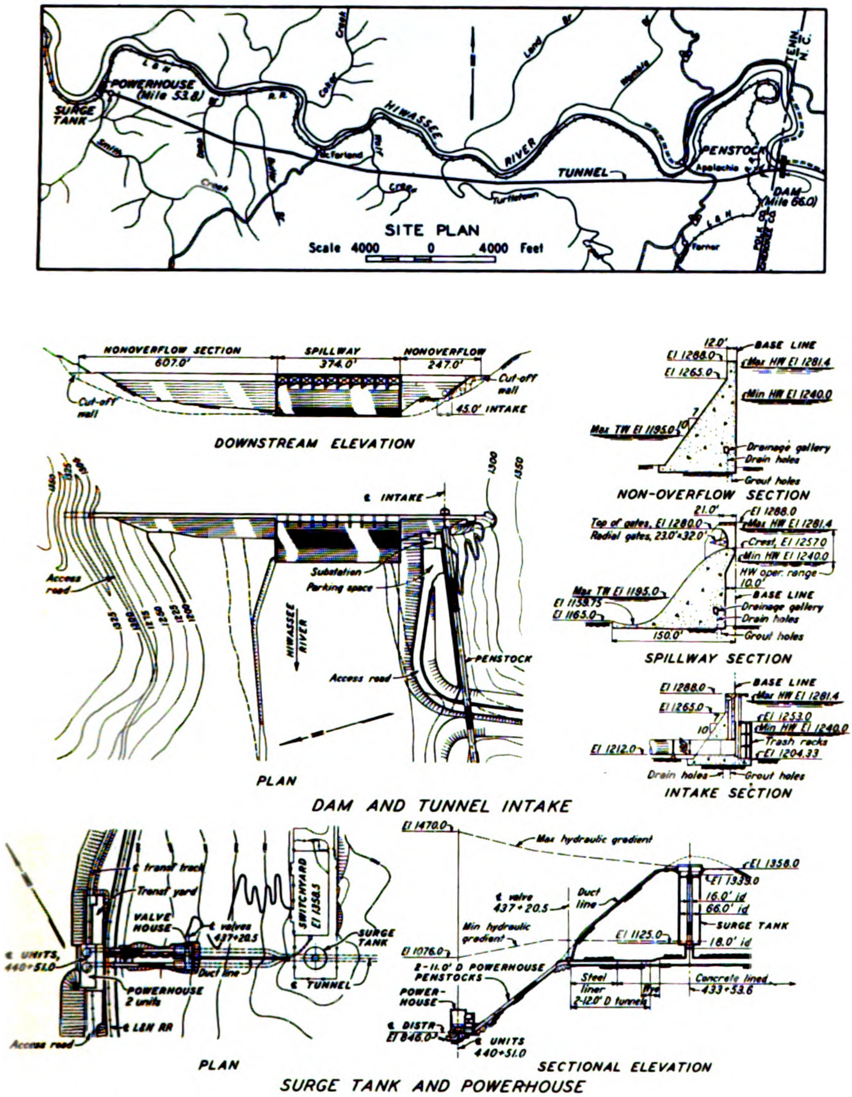


FIGURE 11.—*Typical diversion project—Apalachia—plans, elevation, and sections.*

While these three distinct types of development have been needed to meet the natural conditions at the various sites, a considerable amount of similarity has been achieved between stations of the same type. In the case of Douglas, for instance, which was urgently needed to supply power to war industries, the site happened to be so similar to the site of Cherokee, which was well along in construction, that one of the three generating units on order for Cherokee was transferred to Douglas, and a very similar project arrangement was used. This resulted in great economy in design, a record of rapid construction, and two almost identical stations offering many operating advantages. To a less extent, Guntersville and Chicka-

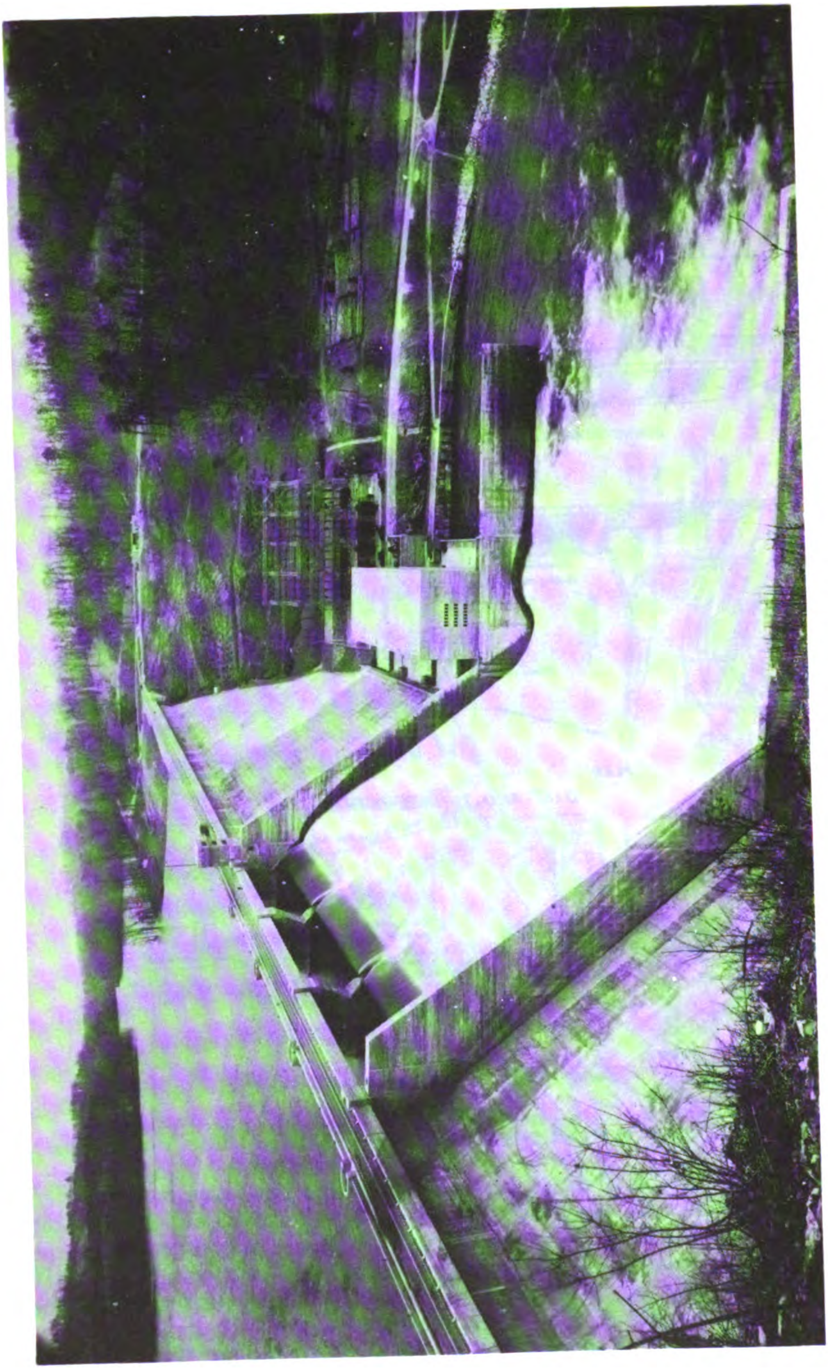


FIGURE 12.—*Norris Project.*

mauga, which also were quite similar sites, were designed with several identical features.

NORRIS

The Norris site on the Clinch River was formerly known as the Cove Creek site. It is 79.8 river miles above the mouth of the Clinch River and 9 river miles below the mouth of the Clinch's principal tributary, the Powell River. As early as 1911 the site had been investigated by power interests because of the excellent energy storage possibilities of the Clinch River Basin. Later it was studied by various other interests including the U.S. Corps of Engineers in connection with development of the entire Tennessee River system. The TVA Act in 1933 named this site as the first to be developed, and soon afterward its name was changed to Norris in honor of Senator George W. Norris, who sponsored the TVA Act.

Authorization, construction, operation, and cost data for the Norris project (fig. 12) are as follows:

Authorized	May 18, 1933
Construction started	November 6, 1933
Closure	March 4, 1936
Unit 1, commercial operation	July 28, 1936
Unit 2, commercial operation	September 30, 1936
Cost of the 2-unit project, including switchyard	$31,500,442

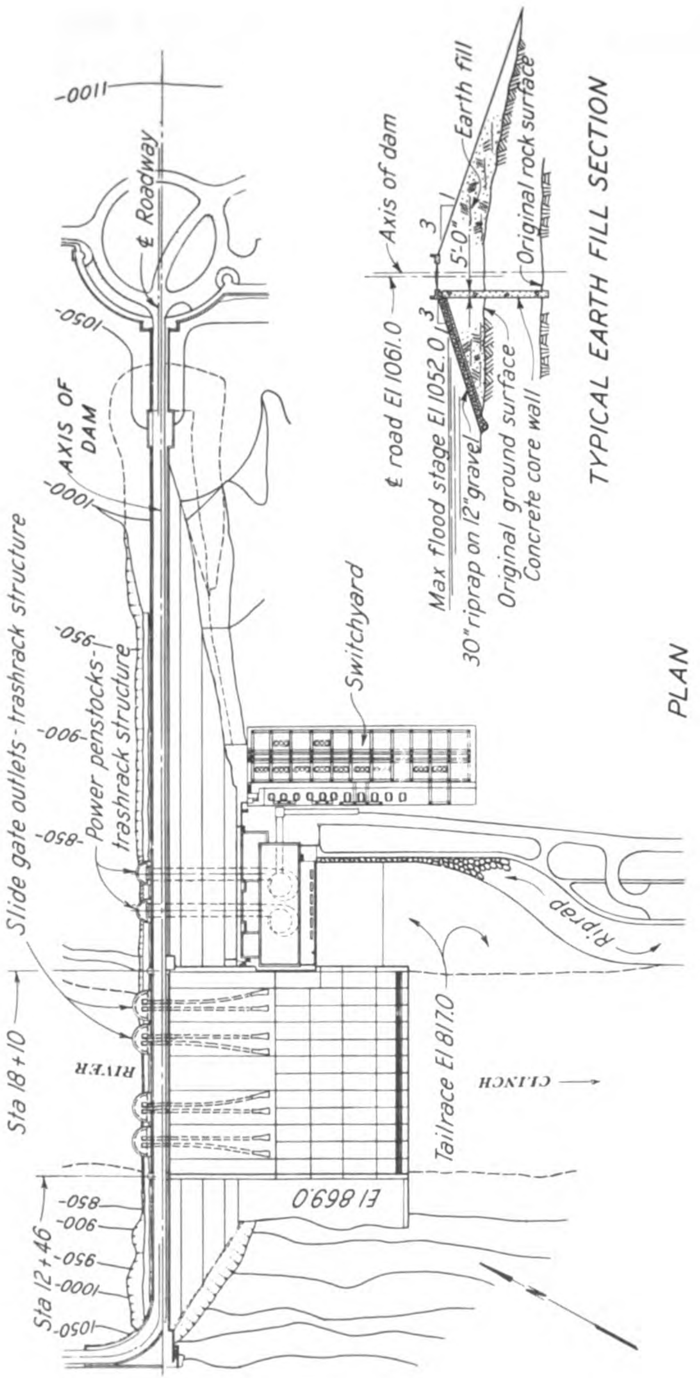
The general layout of this tributary-type project is shown in figure 13. The dam consists of a straight concrete gravity structure for the western 1,570 feet which is connected to the east hillside by a rolled earth embankment, about 290 feet long, with a reinforced concrete core wall. The maximum base thickness of the dam is 208 feet and the greatest height is 265 feet (lowest point in the dam foundation to the roadway).

The exposed rock formation in the original river bottom at the site lay at an average elevation of 818 feet above sea level, and the roadway on top of the dam is at elevation 1061. The crest of the three 100-foot spillway openings is at elevation 1020. Three hydraulically operated steel drum gates are installed along the concrete spillway crests and these gates may be raised to any elevation between 1020 and 1034 to retain flood waters. A concrete-encased steel girder roadway bridge spans the spillway. There are eight outlet conduits, arranged in pairs, through the dam. Each outlet is controlled by 2 vertical sliding gates, 1 for service and 1 for emergency use. These outlets permit a discharge of approximately 36,500 cubic feet per second with the reservoir at elevation 1020.

The powerhouse, 67.5 feet wide by 205 feet long, is situated on the east side of the river against the downstream face of the dam and adjacent to the spillway. A cross section of the powerhouse is shown in figure 14.

Turbines

Two Francis-type hydraulic turbines manufactured by the Newport News Shipbuilding & Drydock Co. provide the power for driving the two 56,000-kilovolt-ampere synchronous generators (fig. 15). Each turbine is rated 66,000 horsepower at 165-foot net head and operates at 112.5 revolutions per minute. Each is designed to


TYPICAL EARTH FILL SECTION
Axis of dam
Earth fill
Original rock surface
5'-0"
3
3
℄ road El 1061.0
Max flood stage El 1052.0
30" riprap on 12" gravel
Original ground surface
Concrete core wall
PLAN
℄ Roadway
AXIS OF DAM
1100
1050
1000
950
900
850
Slide gate outlets - trashrack structure
Power penstocks - trashrack structure
Switchyard
Riprap
Tailrace El 817.0
El 869.0
Sta 18+10
Sta 12+46
RIVER
CLINCH

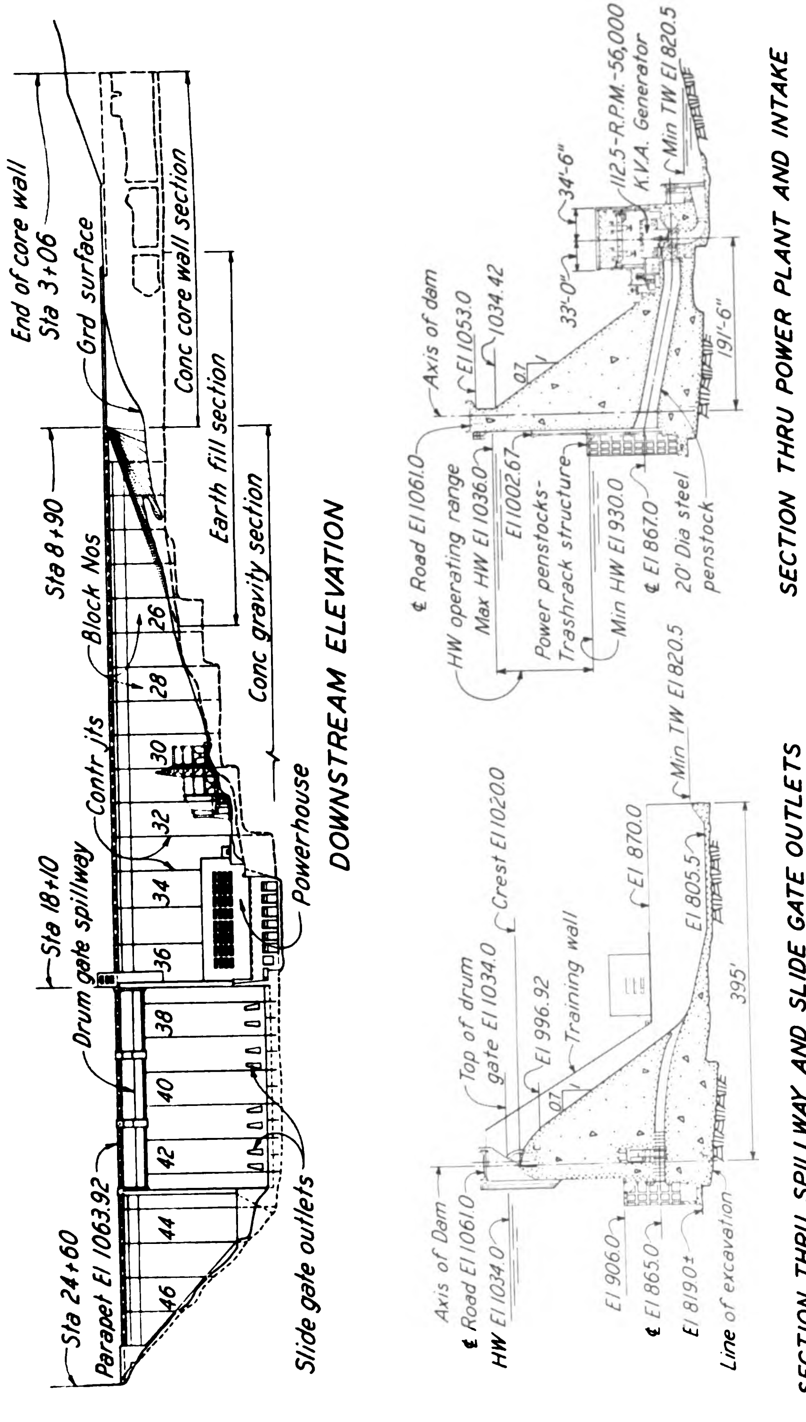


FIGURE 13.—*Norris—plan, elevation, and sections.*

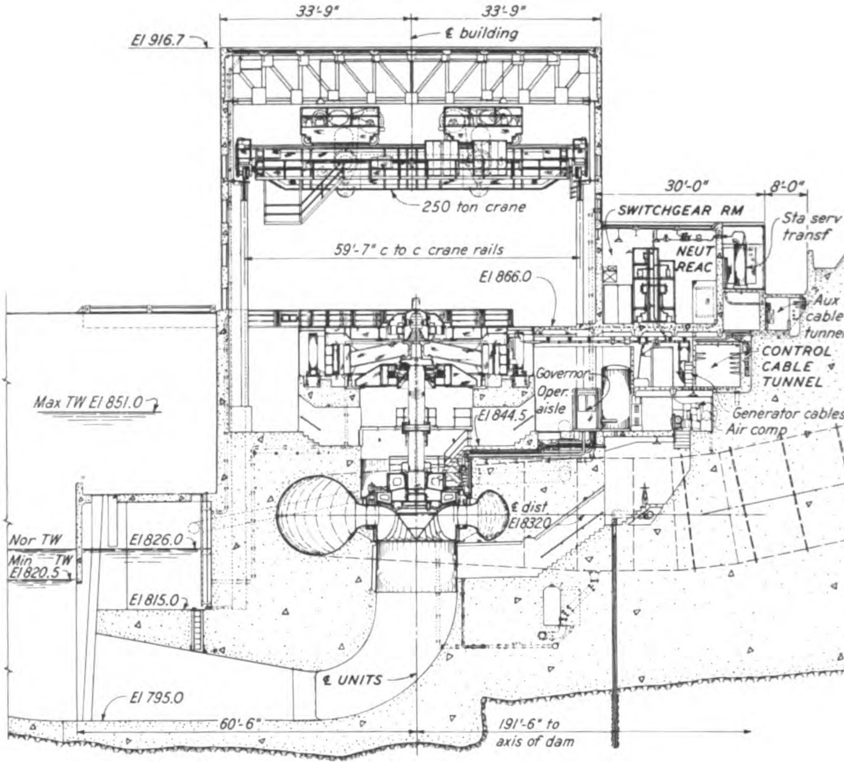
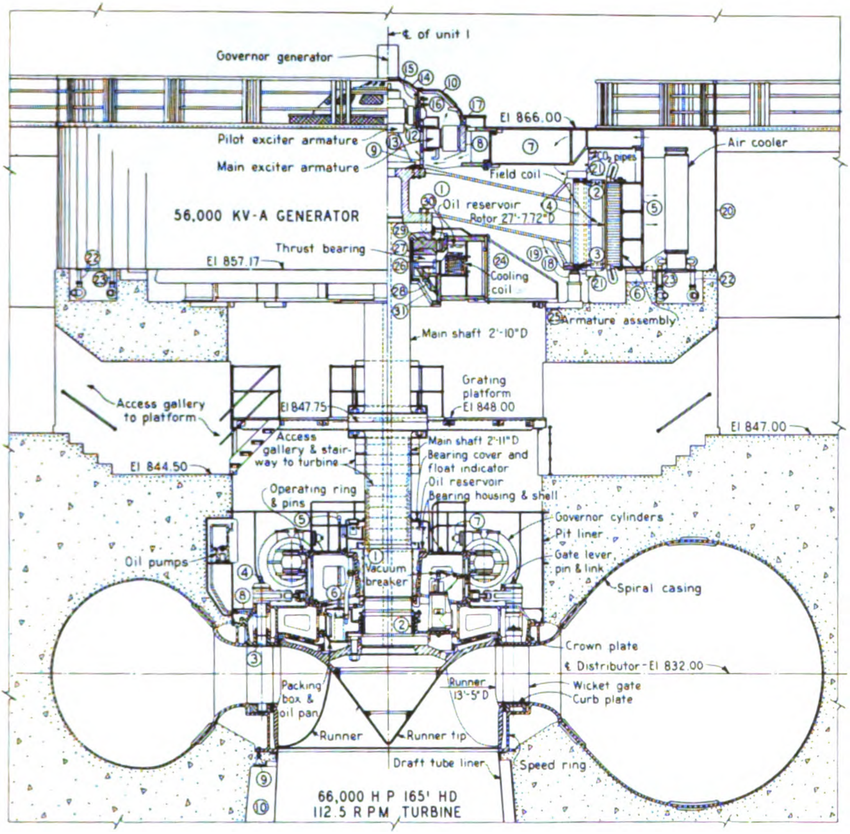


Figure 14.—*Norris powerhouse cross section.*

operate under any net head from 135 feet minimum to 195 feet maximum and has best efficiency at approximately 180-foot net head. Each turbine is also designed to withstand a maximum runaway speed of 220 revolutions per minute. At rated conditions the value of specific speed is 49 and the center line of the runner is placed 6 feet above tailwater giving a plant sigma of 0.16.

The spiral cases, which are of plate-steel riveted construction and are riveted to the cast-steel stay rings, are shown in figure 16. They are designed to withstand the maximum pressure imposed by a combination of maximum head plus water hammer pressure. The runner is of cast-steel construction with 19 buckets. The shaft is guided by an oil-lubricated guide bearing located immediately above the head cover.

Shortly after the initial operation of the first unit an unusual noise and vibration was noticed at certain conditions of gate opening and head. After considerable testing and experimentation it was determined that this condition was being caused by vibration of the runner buckets. The vibration was finally stopped by welding steel structs between the buckets as shown in figure 17. Tests have indicated that the struts do not have any appreciable effect on power output or efficiency.



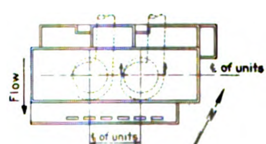
DESCRIPTION OF PARTS

GENERATOR

1. Spider
2. " upper end plate
3. " lower " "
4. " rim punching
5. Frame
6. " sole plate
7. Upper bracket
8. Main exciter frame
9. " " shaft
10. " " support
11. " " W.A.F.
12. Pilot exciter frame
13. " " shaft
14. " " support
15. " " W.A.F.
16. Collector
17. Platform
18. Brake
19. " rim
20. Air housing
21. Blowers
22. Water inlet
23. " outlet
24. Lower bracket
25. " " sole plate
26. Thrust bearing shoe
27. " " runner
28. " " support
29. Guide bearing runner
30. " " shoe
31. Oil pot

TURBINE

1. Guide bearing
2. Packing
3. Gate stem
4. Alemite connection
5. Oil level indicator
6. Oil overflow
7. Governor cylinder check valve
8. Floor plate
9. Leveling jacks
10. " " pedestals



KEY PLAN
Showing Location of Section

Figure 15.—*Section through Norris turbine and generator.*

The turbine acceptance tests conducted on these units is summarized in chapter 3, "Hydraulic Turbines," and a detailed description of the Gibson tests is included in appendix A.

Governors

The governors are of the cabinet-actuator type, manufactured by the Woodward Governor Co. The arrangement of the pumps, tanks, and controls is such that operation can be either as 2 independent unit systems or as 1 twin system.

FIGURE 16.—*Norris—riveted steel scroll case.*

Each actuator is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and necessary auxiliaries. The oil pumps are of the herringbone gear type with a capacity of 219 gallons per minute at 300 pounds per square inch and are driven by 60-horsepower, 400-volt, squirrel-cage motors. Each pressure tank has a capacity of 196 cubic feet and each sump tank a capacity of 120 cubic feet.

In 1953 the required auxiliaries were installed on both turbines and governors to provide for remote control of the units from the control room. This work included the addition of an automatic lubricating system on the turbines.

Generators

The two generators were designed and manufactured by Westinghouse Electric Corp. Each has a normal rating of 56,000 kilovolt amperes, 13,800 volts, 0.9 power factor, and is provided with direct-connected exciter, pilot exciter, thrust and guide bearings, an enclosed ventilating system, surface air coolers, and CO_2 fire protection. A view of the generator room is shown in figure 18.

Oil systems

One 1,200-gallon-per-minute oil purifier with separate distribution piping systems processes the insulating oil for the transformers and oil circuit breakers, and lubricating oil for the generator thrust and guide bearings, governors, and turbine guide bearings. The supply and return lines at the purifier are connected to either oil system through two 2-port, 3-way valves, which are arranged to prevent mixing of oil from one system with the other. The purifier is of

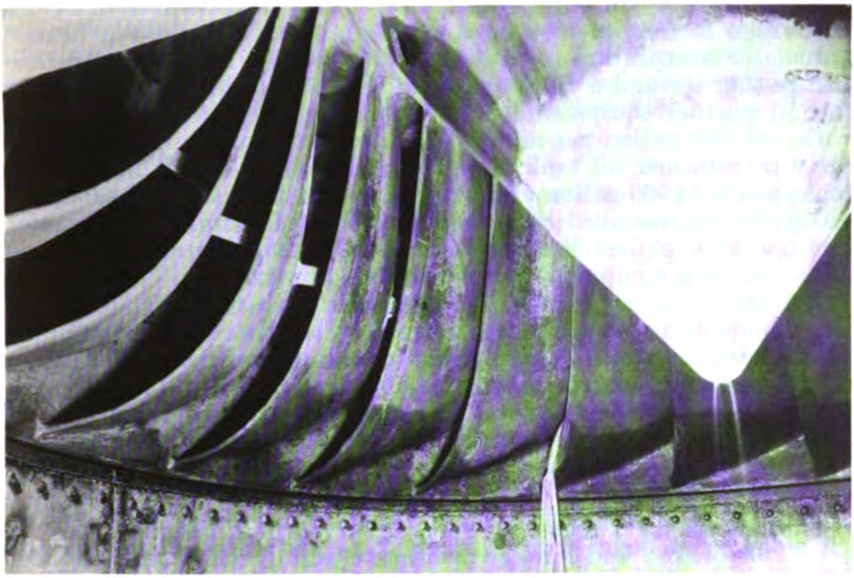


FIGURE 17.—*Struts welded to Norris turbine runner to eliminate vibration.*

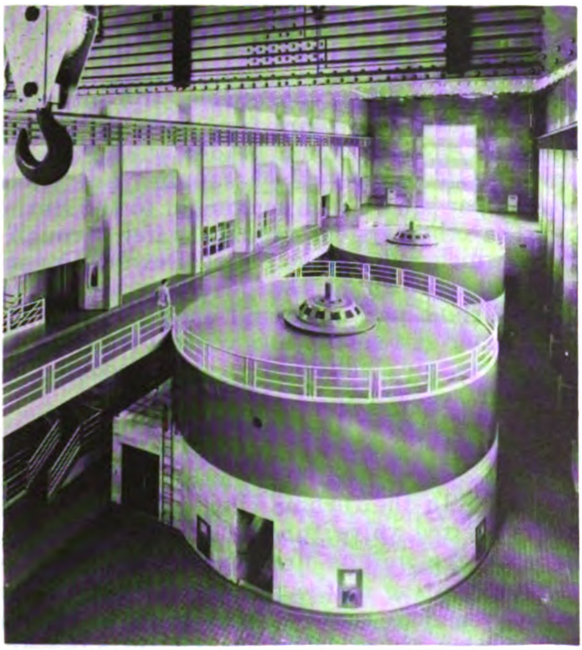


FIGURE 18.—*Norris generator room.*

the combination centrifuge and filter press type, with centrifuge, centrifuge motor, inlet and outlet pumps, strainer, electric heater, automatic temperature control, and filter press. A portable dielectric testing set and a filter paper drying oven are also included in the oil purifier equipment. The insulating oil system is equipped with one 200-gallon-per-minute oil transfer pump, a 12,000-gallon dirty transformer oil tank, an 8,000-gallon dirty circuit breaker oil tank, and a 12,000-gallon clean insulating oil tank. The lubricating oil system is equipped with one 30-gallon-per-minute oil transfer pump, a 2,400-gallon clean oil tank, and a 2,400-gallon dirty oil tank. All tanks and equipment are within the powerhouse.

An oil system is provided for hydraulic operation of the 16 slide gates controlling the discharge from the 8 spillway outlet conduits. This system consists of a 20-gallon-per-minute pump, a 300-gallon oil storage tank, and a piping distribution system to the hydraulic hoists which operate at an oil pressure of 1,000 pounds per square inch.

Compressed air

The station air system for general service use, operation of the generator brakes, and intake trashrack cleaning consists of one 330- and one 45-cubic-foot-per-minute horizontal, single-stage, motor-driven air compressor, both operating at 100-pound-per-square-inch discharge pressure. Air receivers and a piping distribution system are included to provide for a completely automatic-controlled system.

Compressed air for the governor system is supplied independently from an 8-cubic-foot-per-minute, 300-pound-per-square-inch portable compressor.

Raw water system

Raw water for unit cooling, lubrication, and miscellaneous services is supplied by gravity pressure from each unit penstock. Each intake is connected into a common header, through a strainer, and thence to 2 main systems, 1 of which supplies full headwater pressure at 76 pounds per square inch maximum to the station unwatering eductors. The other system supplies water through a pressure regulating valve which reduces the outlet pressure to approximately 30 pounds per square inch to the generator air and bearing oil coolers, and the turbine packing gland and seal rings at each unit. In addition the latter system supplies cooling water to the air compressors, aftercoolers, air-conditioning central cooling coil, and the generator room surface cooler.

At each unit a motor-operated valve serves as a complete shutoff for all cooling and lubricating water. The valve is opened or closed by manual remote control from the control room when the unit is started or stopped. In the turbine ring seal water supply at each unit a solenoid-operated valve functions to shut off the seal water momentarily when the unit is first started motoring, in order to break the vacuum existing at the runner. This valve is opened or closed by manual remote control from the control room. Flow through the generator air coolers is controlled automatically by a motor-operated proportioning valve operated by a temperature con-

troller actuated by a feeler bulb in the generator housing. The raw water systems for the turbines and generators have their own series of alarm circuits operated by flowmeters. The flowmeters in the generator bearing oil coolers have an additional electrical contact to shut down or prevent starting the unit on low flow.

Treated water

Domestic water is supplied by gravity pressure from the town of Norris water system to the powerhouse for the sanitary facilities and for fire protection. A 3- and 4-inch-size main is connected to the town of Norris supply reservoir and a 20,000-gallon storage tank on top of the west embankment of the dam ensures an emergency supply at the powerhouse in the event of failure of the town system. The powerhouse distribution system supplies the domestic needs at a reduced pressure of 60 pounds per square inch and all fire hose outlets and sprinkler systems at full system pressure.

TVA designed, constructed, and operated the water supply system to serve construction needs, the construction camp, and the permanent village which became the town of Norris. The system was originally designed on the basis of 50 gallons per day per capita for an initial population of 2,000 with provisions for possible increase to 4,000. The supply source is a spring on Clear Creek from which the water flows by gravity to the pumphouse where three pumping units, having a total combined pumping capacity of 567,000 gallons per day, and chlorinating equipment are installed. A covered concrete reservoir, 60 feet in diameter and 15 feet deep, provides storage for the distribution system mains which consist of 8-inch, cement-lined, cast-iron pipe. Main line pressures range from 300- to 400-foot head, depending upon their location. Numerous fire hydrants with 2½-inch hose connections were spaced from 500 to 600 feet apart throughout the camp and village. A 650-gallon-per-minute truck pumper with ample hose was provided for fire-fighting purposes.

The complete camp and village water supply system was subsequently sold to the private interests who purchased the town of Norris.

Sewage disposal

Disposal of the sewage from all powerhouse sanitary facilities is through a single septic tank, the effluent of which is discharged into the tailrace.

TVA designed, constructed, and operated the sewage disposal system for the construction camp and village. A maximum daily flow of 200,000 gallons was assumed based on a population of 2,000 and 100 gallons per day per capita. The original design included primary sedimentation, activation, recirculation aeration, secondary sedimentation, spray aeration, and sludge-drying beds of the open type. Sewage enters the plant through a battery of six Imhoff tanks. After construction activities at the dam were completed and the load on the plant decreased, treatment was altered to consist of primary sedimentation, activation, aeration, secondary sedimentation, and sludge drying. A high efficiency is obtained by this method of operation.

Like the camp and village water supply system, the sewage disposal system was also sold to the private interests purchasing the town of Norris.

Drainage and unwatering

Leakage into the lower galleries of the dam is collected into two sumps from which it is discharged to the tailrace by two pumps, one of 800- and one of 22-gallon-per-minute capacity. Higher level drainage in the dam flows by gravity to the tailrace.

Powerhouse substructure drainage is collected in one sump and is discharged to the tailrace by an automatically controlled 300-gallon-per-minute pump and a 6-inch water jet eductor. A 14-inch water jet eductor unwaters the penstock. Formed wells in one draft tube pier for each unit make possible the insertion of a portable pump to unwater the draft tubes. No such pumps have been furnished for this purpose and to date (September 1957) there has been no need for complete unwatering of the draft tubes.

Fire protection

A CO_2 fire extinguishing system is installed in the powerhouse for protection of the generators, the oil purifier room, and the oil storage room. The system consists of 2 banks of 50-pound carbon dioxide cylinders, each bank containing 20 cylinders. The equipment is arranged for an initial discharge of 10 cylinders and a series of 5 delayed discharges of 2 cylinders each to either generator. Either bank can be placed in readiness for automatic operation for the protection of the generators and the other bank placed in reserve. The system is arranged for either thermoelectric, push-button electric, or manual release to the two generators. Additional equipment is provided for release by push-button electric or manual control of 10 cylinders from 1 bank to the oil purifier room and 10 cylinders from the other bank to the oil storage room.

An automatic overhead sprinkler system supplied from the high-pressure treated water system gives protection to the oil purifier, oil storage, and fan rooms. This water system also supplies the fire hose cabinets in the powerhouse.

The switchyard has 2 portable fire extinguishers, 1 on each oil circuit breaker level. These are 40-gallon-capacity, truck-type, foamite extinguishers which are housed in small concrete structures heated by 1-kilowatt electric heaters to prevent freezing.

Service equipment

A machine shop is in the powerhouse adjacent to the erection bay and is not enclosed in a separate room. The machinery and tools provided for normal maintenance work are listed in table 14, page 626.

An elevator having a capacity of 3,000 pounds at a speed of 250 to 300 feet per minute is installed in the dam to convey operating personnel and visitors between the top of the dam and the powerhouse level. Intermediate landings also serve the operating galleries of the dam. Design data covering this machine are included in table 6, page 394.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, offices, and public spaces for the protection of electrical equipment and for human comfort. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters strategically located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

The air-conditioned spaces are served by a combination heating, cooling, and ventilating system complete with fan, electric blast heater, cooling coils, humidifier, filters, air distribution system, piping, and the customary controlling dampers and devices. Cooling and dehumidification are accomplished by circulating lake water through the cooling coils. A summary of the ventilating and heating requirements is as follows:

Cubic feet per minute of air supplied and exhausted	60,350
Kilowatts of installed electric heating	283

WHEELER

Wheeler Dam (fig. 19) is located 274.9 river miles above the mouth of the Tennessee River and approximately 16.5 river miles upstream from the Wilson project. It was named for General Joe Wheeler who, as a member of Congress from Alabama, introduced a bill in 1898 providing for the development of Muscle Shoals as a power and navigation project. Although no construction was undertaken at that time, this bill was the first of a series which ultimately led to passage of the TVA Act in 1933. Authorization, construction, operation, and cost data are as follows:

Authorizations:	
Project and units 1 and 2	September 21, 1933
Units 3 and 4	July 31, 1939
Units 5 and 6	January 15, 1942
Units 7 and 8	August 12, 1947
Construction started	November 21, 1933
Closure	October 3, 1936
Commercial operation:	
Unit 1	November 9, 1936
Unit 2	April 14, 1937
Unit 3	January 12, 1941
Unit 4	March 13, 1941
Unit 5	October 30, 1948
Unit 6	February 23, 1949
Unit 7	December 31, 1949
Unit 8	March 4, 1950
Cost of the 8-unit project, including switchyard	$48,237,341

The principal structures of this main river project, which are shown in figure 20, consist of dam, navigation lock, power plant, and switchyard. The overall length at the top of the dam is 6,502 feet, including 2,700 feet of spillway, the nonoverflow and trashway sections, the powerhouse, and a 60-foot-wide, 360-foot-long lock cham-

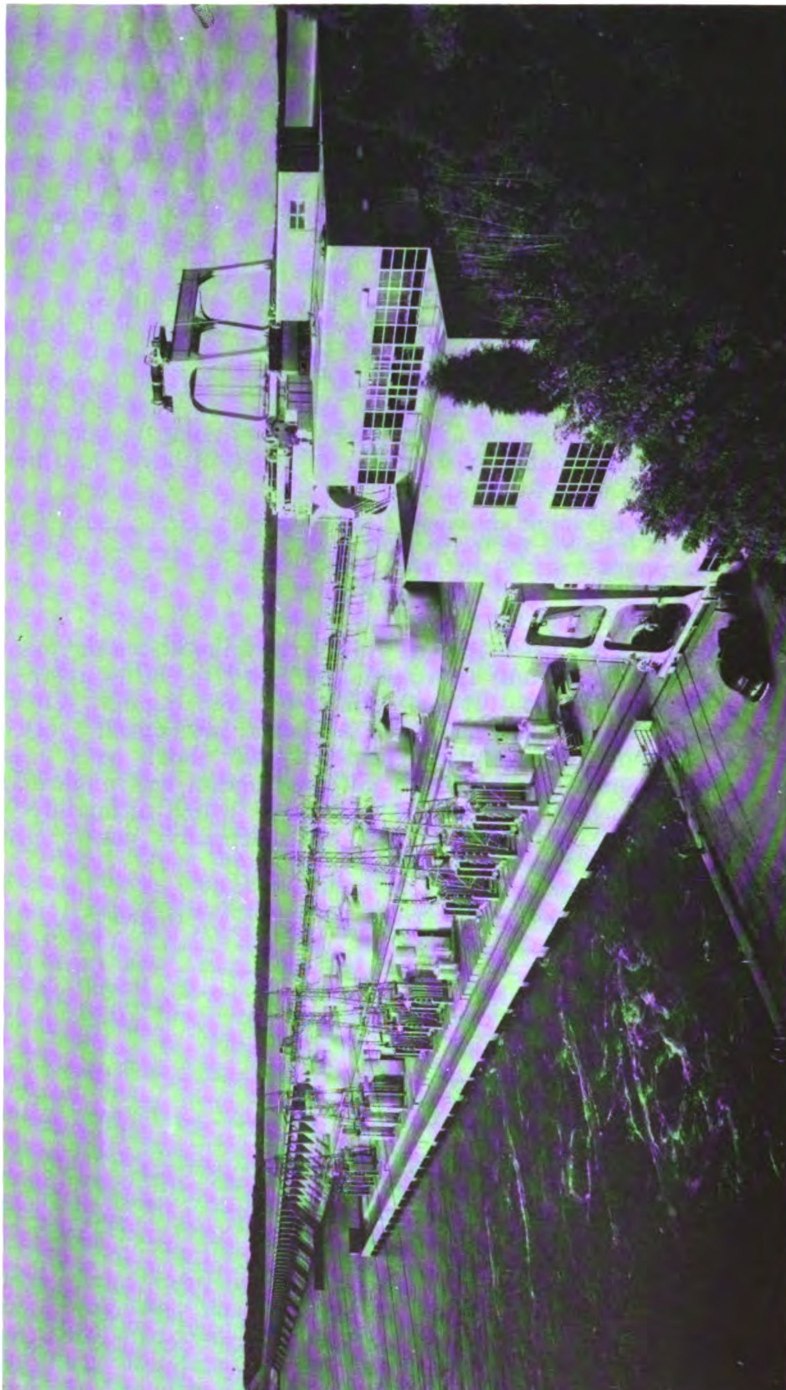


FIGURE 19.—*Wheeler project.*

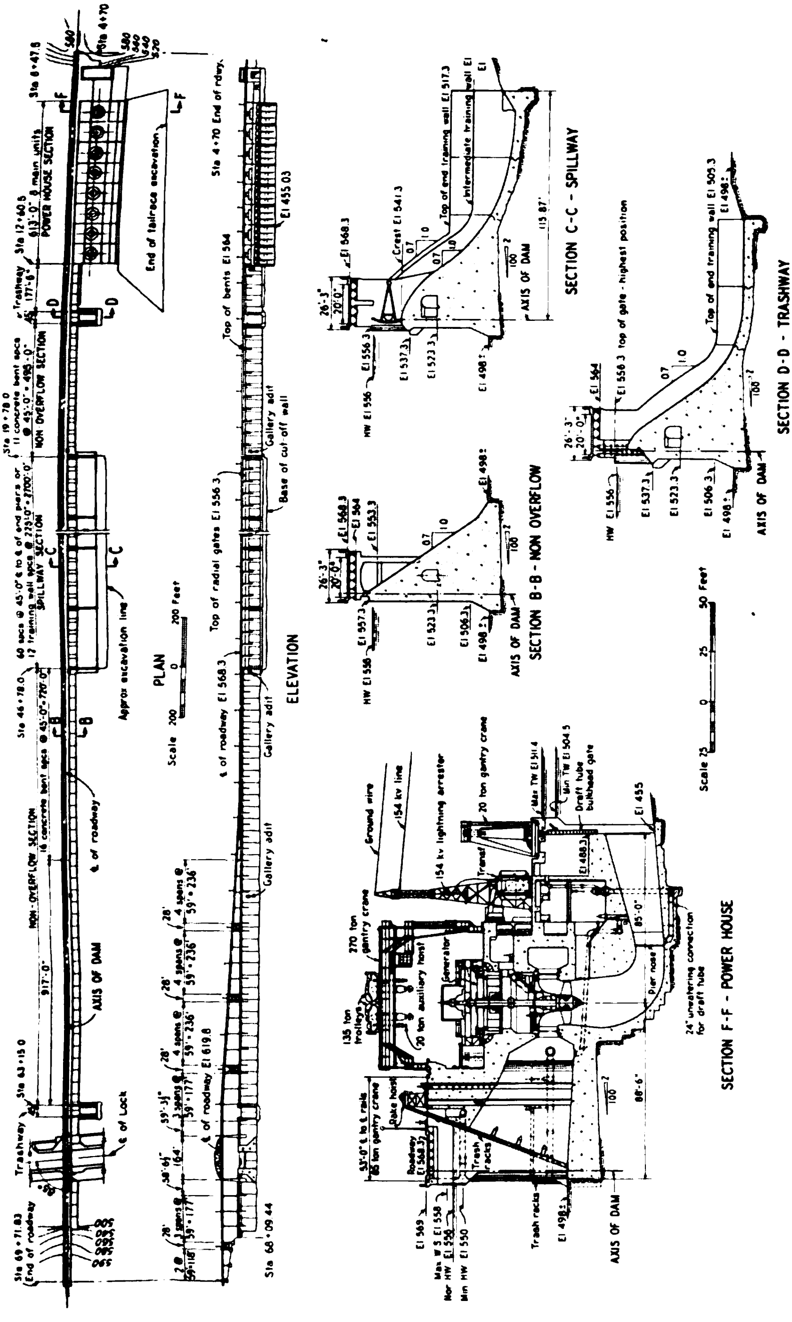


FIGURE 20.—*Wheeler—plan, elevation, and sections.*

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ber. The dam, which is a straight concrete gravity structure, has a maximum base width of 58 feet and height of 72 feet. The spillway, which is designed for passage of a maximum flood of 687,000 cubic feet per second, is equipped with 60 tainter gates, 40 feet long and 15 feet high, which are operated by individual motor-controlled hoists. Two 40-foot-wide trashway sections are serviced by vertical lift rolling gates operated by motor hoists.

The powerhouse, which is located on the south side of the river, is the TVA's first semioutdoor type plant. The powerhouse is 738 feet long including the service bay and 178 feet wide including the intake structure. A cross section of the powerhouse is shown in figure 21.

Turbines

Eight fixed-blade propeller-type turbines, manufactured by the Baldwin-Lima-Hamilton Corp., are direct-connected to the 36,000-kilovolt-ampere synchronous generators. Each turbine is rated 45,000 horsepower at 48-foot net head operating at a speed of 85.7 revolutions per minute. They are designed to operate under any head from a minimum of 44 feet to a maximum of 54 feet. The turbines are also designed to withstand a maximum runaway speed of 160 revolutions per minute. At rated conditions the value of specific speed is 144 and the centerline of the runner is 6 feet below tailwater giving a plant sigma of 0.89. A section through the turbine and generator is shown in figure 22.

These units have concrete spiral cases (fig. 23) with cast-steel stay rings. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The six cast-steel blades of the runner are keyed to a cast-steel hub at a pitch of about 21 degrees

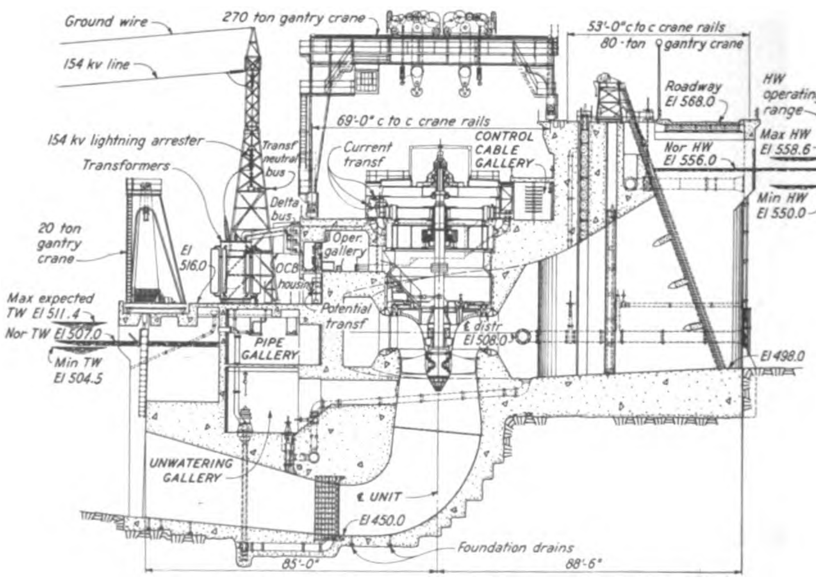


FIGURE 21.—*Wheeler—powerhouse cross section.*

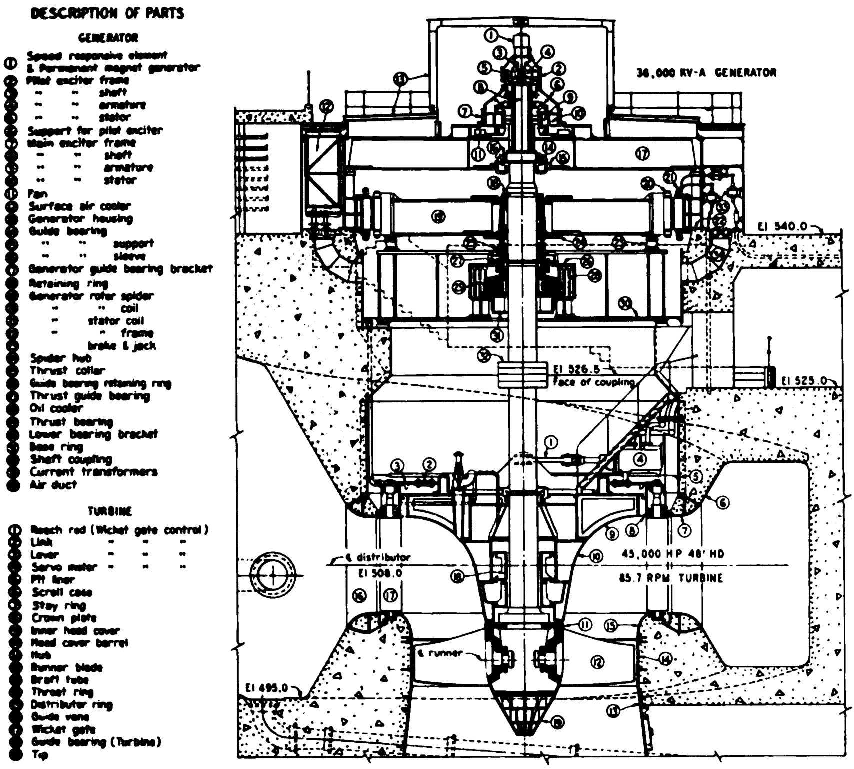


Figure 22.—*Section through Wheeler turbine and generator.*

at the tip. Both front and back of the blades are finished smooth by grinding and a ¾-inch stainless steel strip 36 inches long is welded to the end of each blade near the discharge edge to resist cavitation. The shaft is guided by a water-lubricated guide bearing located directly above the head cover. The earlier units were equipped with rubber-lined guide bearings; however, on the later units the TVA has specified molded plastic or "Insurok" for the bearing material.

Official capacity tests conducted on units 1 and 2 in April 1937 indicated the following outputs:

Unit	Head (feet)	Kilowatts		Horsepower	
		Indicating meter	Actual	Tests	At 48-foot head
1	49.90	37,000	37,680	51,600	48,700
2	50.05	37,250	38,100	52,200	49,000

Since the output guaranteed was 45,000 horsepower at 48-foot head, the power exceeded the guarantee by approximately 4,000 horsepower or slightly over 8 percent.

FIGURE 23.—*Wheeler—concrete scroll case.*

Efficiency tests of the units were made on a 16-inch model in the hydraulic laboratory of the turbine manufacturer. The model was homologous with the prototype and included draft tube, runner, scroll case, intakes, and racks. Tests were conducted under actual heads of from 3 to 4 feet but over a wide prototype range of heads that were obtained by varying the test speed of the model. The model tests indicated the following field performance for the prototype:

Head (feet)	Efficiency (percent)	Horsepower
48	92.8	44,000–45,000
43	92.1	38,000–40,000

Governors

The governors are the cabinet-actuator type, manufactured by the Woodward Governor Co. The arrangement of the pumps, tanks, and controls is such that operation can be either as independent unit systems or as twin systems (fig. 24).

Each actuator is complete with governor head, sump tank, two pressure tanks, oil pump, permanent magnet generator, and the

necessary auxiliaries for control of the turbine from the actuator. The oil pumps are the herringbone gear type with a capacity of 300 gallons per minute at 300 pounds per square inch and are driven by 100-horsepower motors. Each pressure tank has a capacity of 196 cubic feet making a total of 392 cubic feet for each unit. The sump tank capacity is 135 cubic feet.

Generators

The generators, which were manufactured by General Electric Co., have a normal rating of 13,800 volts, 36,000 kilovolt-amperes, or 32,400 kilowatts at 0.9 power factor. The main exciter and pilot exciter are mounted above the main rotor and are driven by the main shaft. An enclosed air-circulating system, cooled by water, and CO_2 fire protection are provided. One guide bearing is above the rotor, and one combination guide and thrust bearing is below the rotor. The shell of the generator air cooler housing is insulated on the inside for reduction of heat from solar radiation due to the outdoor-type installation.

Oil systems

The oil purification system for the insulating oil in the transformers and oil circuit breakers and the lubricating oil in the generator and governor consists of one 1,200-gallon-per-hour purifier with centrifuge and filter press, a 50-gallon-per-minute lubricating oil transfer pump, and a 100-gallon-per-minute insulating oil transfer pump. Storage is provided by one 12,000-gallon dirty transformer oil tank, one 12,000-gallon clean insulating oil tank, one 7,500-gallon dirty circuit breaker oil tank, one 5,000-gallon dirty lubricating oil tank, and one 5,000-gallon clean lubricating oil tank. An additional 220-gallon tank under air pressure serves various plant uses of lubri-

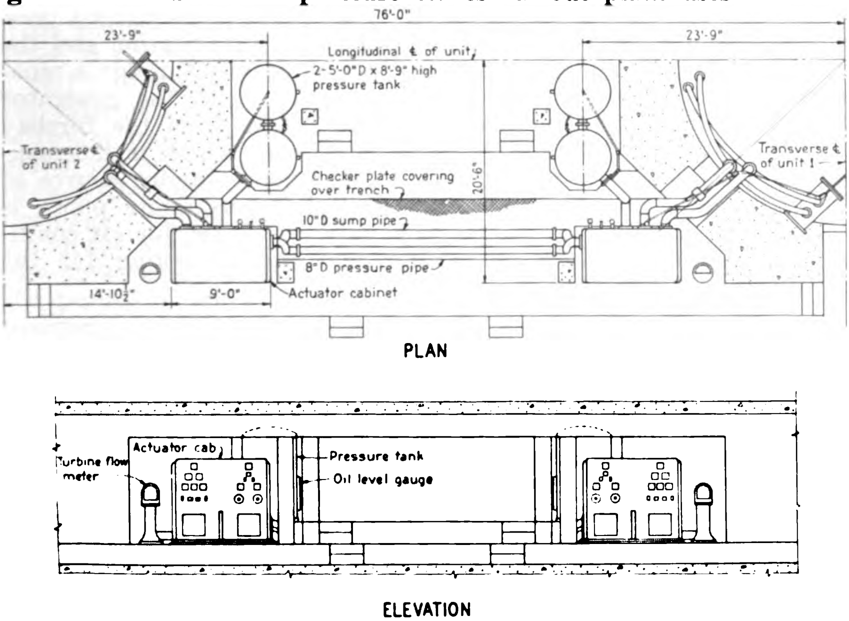


FIGURE 24.—*Wheeler units 1 and 2—arrangement of governors.*

cating oil. There is a direct-connected piping system between the generators, governors, and the lubricating oil purification equipment. The transformers and reactors are also directly connected to the insulating oil system but the switchyard oil circuit breakers are supplied with hose connections for filling and draining.

Compressed air

Station service and draft tube evacuation air are provided by three stationary air compressors, each complete with aftercooler, operating at a discharge pressure of 100 pounds per square inch. Two machines are rated 330 cubic feet per minute and one machine is rated 95 cubic feet per minute. There are 2 air receivers for station service use and 4 receivers, totaling 2,800 cubic feet, for storage of draft tube evacuation air. The evacuation system is used for motoring units 3–8. The kilowatt input to the generator when motoring with compressed air varies between 700 and 1,000 kilowatts. A separate 30-cubic-foot air receiver stores air at 100 pounds per square inch for the generator air brakes, thereby ensuring an adequate pressure for this service since the evacuation system during an initial unit blowdown causes a considerable drop in station air pressure.

An 8-cubic-foot-per-minute, 300-pound-per-square inch portable air compressor originally operated the units 1 and 2 governor systems. When the additional generating units were installed, this compressor was converted into a stationary unit, and a piping system with a small receiver was connected directly to each of the governor system pressure tanks for all units.

Raw water system

Each unit has a raw water intake in the scroll case, a twin-type strainer, and a 1,300-gallon-per-minute pump which supplies water to the generator air and oil coolers. This water is discharged back into the scroll case. Water for turbine bearing lubrication and the wheel pit drainage ejector normally flows by gravity through a separate strainer; however, there is a connection with the generator pumped system for emergency use. An intake from the forebay has a 1,300-gallon-per-minute emergency pump which is interconnected with each unit cooling water system as a standby source in the event of a pump failure. An 800-gallon-per-minute pump is connected to the forebay system to supply raw water for air conditioning use, air compressor cooling, and engine cooling for the auxiliary power generator.

Treated water

A permanent water purification plant for sanitary and fire protection uses is in the service bay of the powerhouse. This plant serves the needs of the power plant, village, lock, and lock operators' residences. It has a capacity of 100,000 gallons per day (24-hour basis) and treatment consists of mixing, coagulation, rapid sand filtration, dry chemical feeding, and chlorination. Raw river water is supplied to this plant from the forebay intake. Two high head service pumps deliver treated water to the 25,000-gallon elevated storage tank in the village which is a source of gravity pressure to the powerhouse. During the construction of units 3 and 4 a main

line was extended through the inspection gallery of the dam to a new 25,000-gallon elevated storage tank located in the lock operators' village. A booster pump was installed in the lock to pump water into the new tank which supplies the sanitary water needs and fire protection in the lock area.

The original construction needs for treated water were supplied by a temporary filtration plant having a 24-hour capacity of 48,000 gallons. Raw water was obtained from the river for treatment which consisted of coagulation, rapid sand filtration, and chlorination.

Sewage disposal

Waste from all sanitary fixtures in the control building discharges into a septic tank located in the southwest corner of the control building. The effluent is discharged into the tailrace. In designing units 3–8 a new toilet room and kitchen were included for the turbine operators in the operating gallery. Waste from these facilities is discharged into a small septic tank, the effluent of which is carried to the tailrace.

A complete sewerage system was built to serve the needs of the construction camp and village. An Imhoff tank was located about 2.000 feet downstream from the powerhouse with its effluent being carried to the tailrace.

Drainage and unwatering

All building drainage above maximum tailwater level is discharged by gravity into the tailrace. An unwatering pump is provided in the service bay basement which collects all drainage from the lower levels of the structures. Two float-controlled, deepwell-type station drainage pumps, each having a capacity of 400 gallons per minute, automatically discharge sump drainage to the tailrace. This sump also contains two scroll case unwatering pumps, each rated at 4,500 gallons per minute. The original installation of units 1 and 2 provided formed wells in each of the two draft tube piers for each unit with the top of the well sealed with a cover against tailwater pressure. It was contemplated originally that two 2,500-gallon-per-minute portable unwatering pumps would be inserted in these wells during a unit unwatering period to discharge draft tube drainage through an embedded header to the station sump from which the water would be repumped to the tailrace by the two scroll case unwatering pumps. A monorail hoist was constructed above the pumps to move them from unit to unit. This did not prove practical and the system was changed to make a permanent installation of two 2,500-gallon-per-minute pumps for each unit with their combined discharge being carried directly to the tailrace. Inasmuch as the original construction of units 1 and 2 included the building of the draft tube piers with formed wells for all eight units, this system of draft tube unwatering had to be carried out for all the remaining additional units.

The original construction also included an embedded 30-inch header in the unwatering gallery floor to which each of the unit scroll cases drained through valved connections. This header conveyed the drainage to the station sump from which it was discharged

to the tailrace by the two 4,500-gallon-per-minute unwatering pumps. In constructing units 3–8 this header was extended at the reduced size of 24 and 16 inches, and 16-inch valved scroll case drain and fill lines are connected to it at each unit. The scroll case drains of these units are also valved to the draft tube for refilling purposes. The original installation also provided a 36-inch intake line from the forebay connected to the unit 1 scroll case for refilling the draft tubes and scroll cases after unwatering. It was planned to interconnect the scroll cases of each unit so that filling could be accomplished from an adjacent unit. Damage to the draft tube gates resulted from use of this system for filling as the gates were not designed for headwater pressure. In designing units 3–8 a new 16-inch valved filling line was provided by connecting the 24- and 16-inch header to tailwater and by proper valving the draft tubes and scroll cases of any unit may be refilled from tailwater to tailwater elevation.

Fire protection

CO_2 fire extinguishing systems serve the main generators. The metalclad switchgear equipment for units 1 and 2 only were also protected by a CO_2 system. Switchgear housings for units 3–8 which are located on the transformer deck have large drains to dispose of oil leakage and no fire-extinguishing system is built in.

Water fire protection is provided throughout the plant from the treated water system by 1½-inch fire hose racks and by 2½-inch hose outlets on the observation terrace above the generating units and on the transformer deck. Automatic water sprinkler systems are installed in the oil purification room and the two oil storage rooms. Each of the three phases of the four transformer banks are provided with manually operated, dry-type, water spray protection systems. A booster pump having a capacity of 800 gallons per minute at 190-foot head gives sufficient pressure at the spray heads. These systems are described in detail in chapter 13, "Fire Protection."

Service equipment

The completely equipped machine shop is located in a separate room adjacent to the erection bay. A detailed listing of the machine tools is given in table 14, page 626.

An automatic push-button-controlled elevator, having a live load capacity of 5,000 pounds at a speed of 250 feet per minute, is in the control building for the use of operating personnel and visitors. This machine serves all operating floor levels and the visitors' lobby. Design data covering this machine are included in table 6, page 394.

An emergency auxiliary power generating unit is installed in a separate room of the control building. This machine has a 200-kilovolt-ampere, 3-phase, 60-cycle, 2,400-volt, 0.8 power factor generator with 125-volt, direct-connected exciter, driven by a 290-brake horsepower, 8-cylinder, 1,200-revolution-per-minute gasoline engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, lobby, reception room, and offices for the protection of electrical equipment, and for

human comfort. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Cooling in the main operating gallery improves comfort conditions during warm weather. Electric unit heaters located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

The air-conditioned spaces are served by a combination heating, cooling, and ventilating system complete with fan, 2 refrigerant compressors, 1 water-cooled condenser, electric blast heaters, cooling coils, humidifier, filters, air distribution system, and controlling devices. Cooling for the main operating gallery (fig. 25) of the units is accomplished by circulating lake water through cooling coils located in the supply air to the gallery.

FIGURE 25.—*Wheeler operating gallery.*

PICKWICK LANDING

Pickwick Landing Dam, the second of the main river dams to be constructed by TVA, is located in the State of Tennessee 206.7 miles above the mouth of the Tennessee River and 52.7 miles downstream from Wilson Dam. The reservoir lies in the southwestern part of Tennessee, northeastern Mississippi, and extends through northern Alabama to Lock and Dam No. 1 at Florence, Ala. The project is named for the Pickwick Landing Community whose first local postmaster named the post office Pickwick in honor of the Pickwick Papers by Charles Dickens. Investigation of the project was begun by TVA in August 1934. Pickwick was the first project to be completely designed by TVA except for the navigation lock which was designed by the U.S. Army Engineers. Because it was the initial design project, many TVA design standards and procedures were

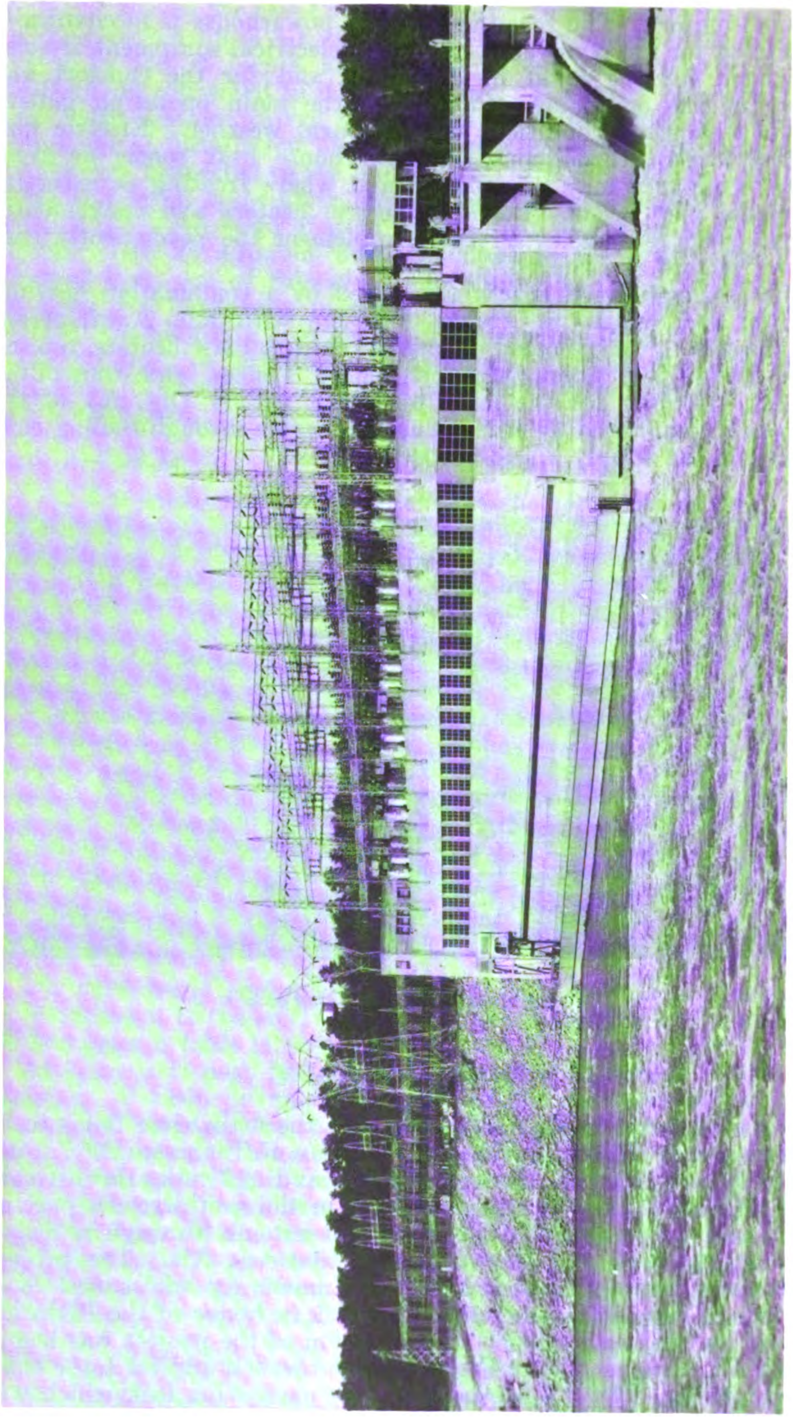


FIGURE 26.—*Pickwick Landing switchyard and powerhouse.*

developed in the course of the job which were very useful in the preparation of similar features on the later designed main-river TVA projects. Pertinent chronological and cost data are as follows:

Authorizations:	
Initial project (including units 1 and 2)	November 19, 1934
Unit 4	March 21, 1940
Unit 3	August 2, 1940
Units 5 and 6	June 28, 1949
Construction started	December 20, 1934
Closure	February 8, 1938
Commercial operation:	
Unit 2	June 29, 1938
Unit 1	August 18, 1938
Unit 4	June 12, 1942
Unit 3	August 12, 1942
Unit 5	October 31, 1952
Unit 6	December 31, 1952
Cost of the 6-unit project, including switchyard	$47,042,884

The Pickwick project consists of the south earth embankment, navigation lock, concrete gravity spillway section, powerhouse, north concrete nonoverflow section, and the north earth embankment which is surmounted by the switchyard. Figure 26 shows the powerhouse and switchyard. The over-all length of the dam is 7,715 feet, and its maximum height is 113 feet from foundation to top of intake section deck. The plan, elevation, and typical sections are shown in figure 27. The navigation lock has a chamber 110 feet wide by 600 feet long and a maximum lift of 63 feet which, when built, was one of the highest in existence. The spillway, which extends 1,141 feet across the original river channel, has twenty-two 40-foot-wide by 20-foot-high fixed roller-type gates operated by two 80-ton traveling gantry cranes.

The powerhouse structure is 580 feet in length, consisting of an intake, electrical bay, generator room, and service bay. A cross section through one of the generating units is shown in figure 28.

Turbines

Six Kaplan-type hydraulic turbines manufactured by the Allis-Chalmers Manufacturing Co. are direct-connected to the 40,000-kilovolt-ampere synchronous generators. Each turbine is rated 48,000 horsepower at 43-foot net head and operates at a speed of 81.8 revolutions per minute. They are designed to operate under any head from a minimum of 30 feet to a maximum of 60 feet and to withstand a maximum runaway speed of 298 revolutions per minute. At rated conditions the value of specific speed is 163 and the centerline of the runner is 9½ feet below tailwater giving a plant sigma of 0.98. A section of the turbine and generator is shown in figure 29.

These units have concrete spiral cases with cast-steel stay rings. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners for units 1 through 4 each have six cast-steel blades set in a hub which contains the levers and cross head for tilting the blades. Certain areas of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is

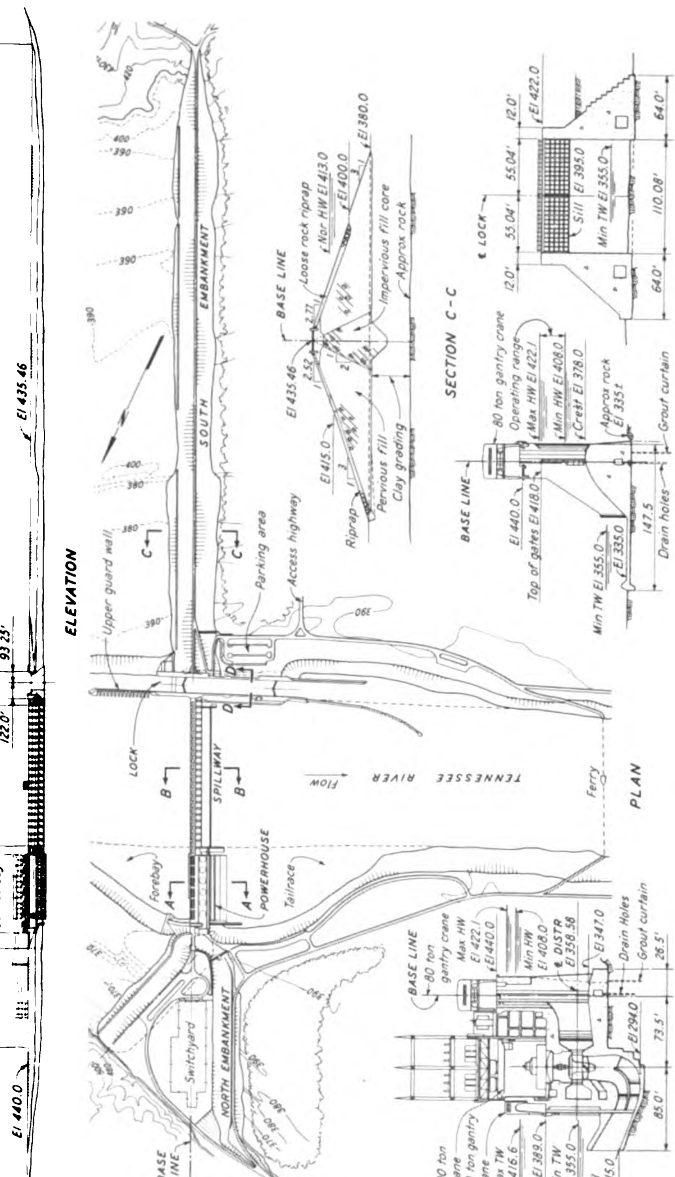


FIGURE 27.—*Pickwick Landing—plan, elevation, and sections.*

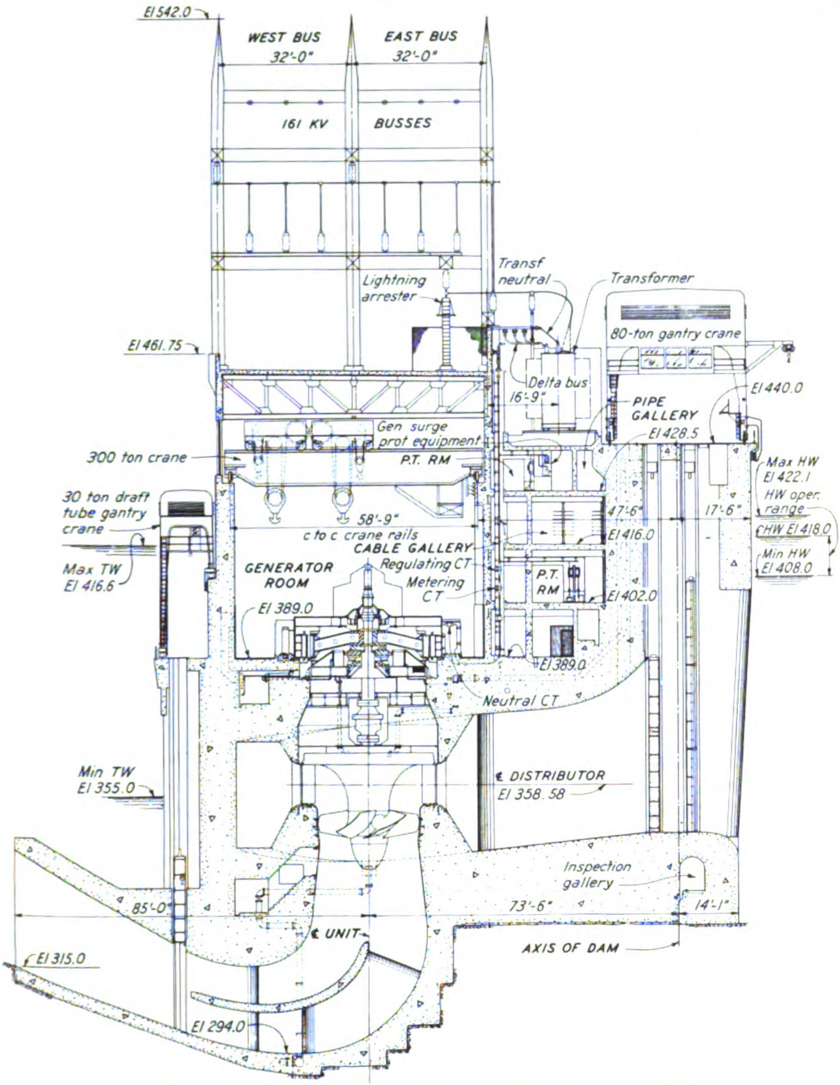
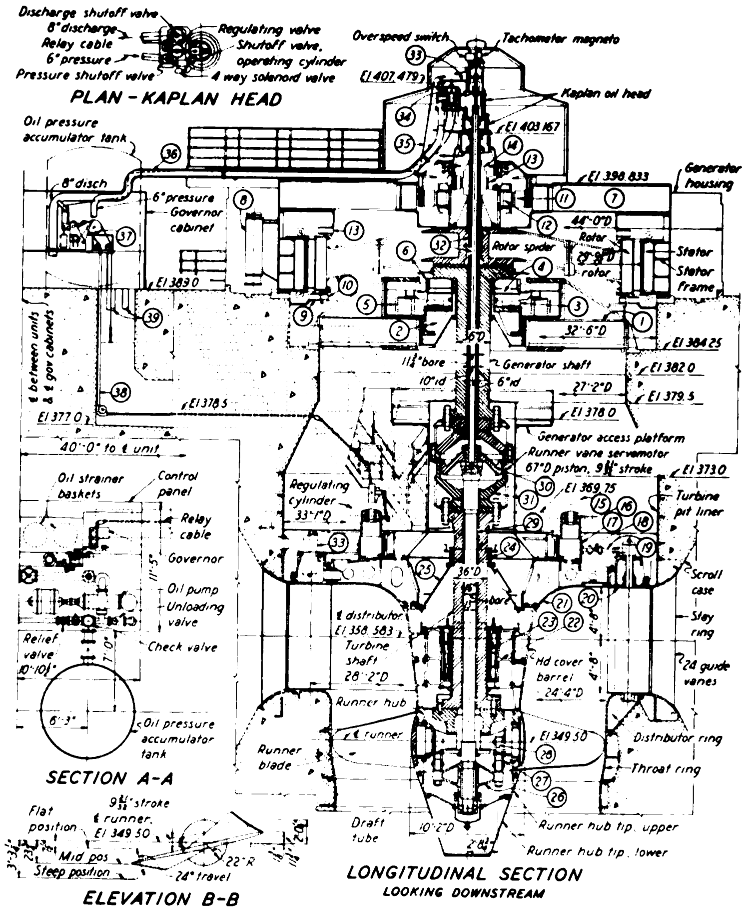


FIGURE 28.—*Pickwick Landing powerhouse cross section.*

guided by a water-lubricated guide bearing located above the head cover. The earlier units were equipped with lignum-vitae bearings; however, on the later units the TVA has specified molded plastic or Insurok for the bearing material. At the time that units 5 and 6 were purchased the manufacturer furnished a 5-blade runner of new design in place of the original 6-blade runner. The new runner is the same size as those of the original units but is more powerful and more efficient. One of the runner assemblies is shown in figure 30.

In preliminary operation of the first unit it was found that when load on the generator was 15,000 kilowatts, the turbine became very noisy. By changing the blade tilt from 31 to 15 percent, most of the noise disappeared. Tests conducted to determine the proper



GENERATOR
3 ϕ 13.8 kv, 40,000 kva @ 0.9 pf

1...Thrust bearing bracket
2... " " support
3... " " shoes
4... " " runner plate
5... " " oil coolers
6...Generator guide bearing
7... " upper bracket
8... " air coolers
9... " air fans
10...Brakes and jacks
11...Main exciter field
12... " " armature
13...Pilot exciter field
14... " " armature

TURBINE
Capacity 48,000 hp, head 43 ft, speed 81.8 rpm

15...Cylinders, gate servomotors
16...Reach rods " "
17...Shifting ring, gate operating mechanism
18...Links, wicket gate control
19...Levers, " " "
20...Outer head cover plate
21...Intermediate head cover plate
22...Turbine guide bearing housing
23... " " "
24... " stuffing box
25... " shaft and stuffing box support
26...Runner blade operating mechanism, cross head
27... " " " " links
28... " " " " levers
29... " " " " servomotor piston rod
30...Runner blade operating mechanism, servomotor piston
31... " " " " " cylinder
32...Runner blade operating mechanism, oil supply pipes
33...Kaplan, runner blade control, restoring mechanism
34...Kaplan, runner blade control valve
35... " " " " " operating cable
36...Kaplan, runner blade control, oil supply pipes
37... " " " " adjusting cone
38...Restoring cable relay from gate servomotors
39...Oil supply pipes to gate servomotors

FIGURE 29.—*Pickwick Landing turbine and generator section and governing system.*

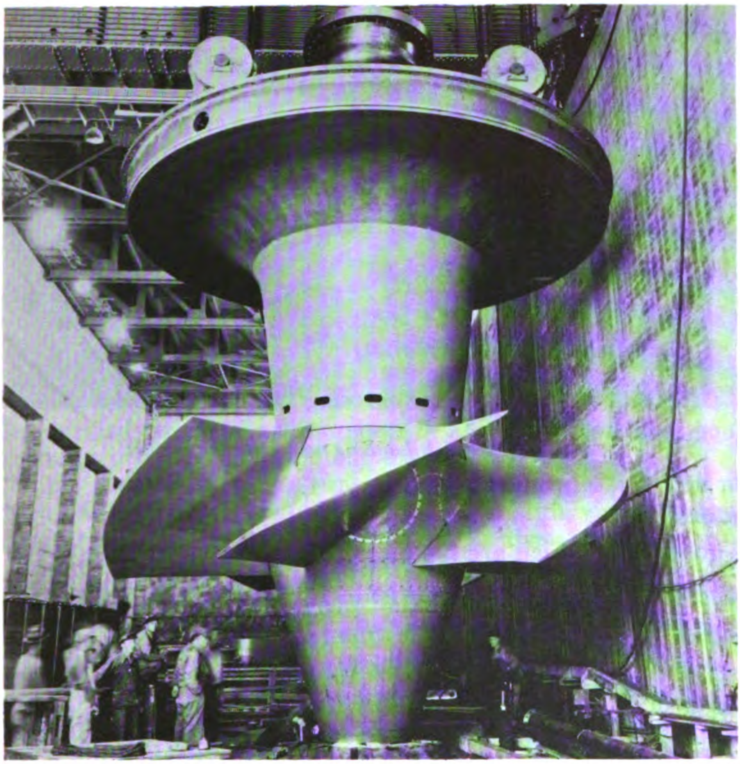


FIGURE 30.—*Assembling Pickwick Landing turbine runner.*

blade tilt for loads of 32,000 to 35,000 kilowatts developed that 50 percent tilt was best. Some difficulty was also initially experienced with the Kaplan control and the blade servomotor which could not change the blade tilt from steep to flat at a governor oil pressure of 300 pounds per square inch when the unit was loaded to 20,000 kilowatts or more. This was due to a hydraulic unbalance of the runner vanes. These difficulties were ultimately corrected by the turbine manufacturer.

The official turbine acceptance test on the initial unit was conducted at the turbine manufacturer's laboratory on a model having a draft tube, discharge ring, scroll case, speed ring, guide vanes, runner and intake (without trashracks) homologous to the prototype, the ratio of all parts of the model to the prototype being 1 to 23.5. Test results stepped up to those expected for the prototype showed the following efficiencies:

Head (feet)	Efficiency (percent)	
	Based on model test	Guaranteed
43	91.1	89
50	92.2	89.3
56	92.6	89.5

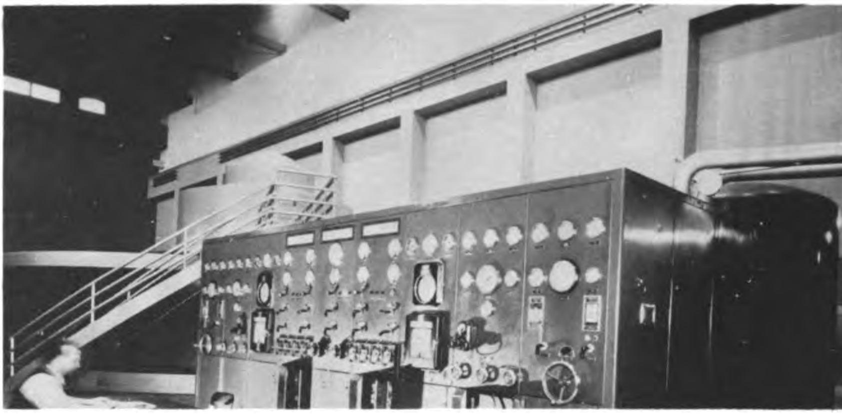


FIGURE 31.—*Pickwick Landing twin governor cabinet.*

Governors

The governors, which are the main cabinet-actuator type manufactured by the Allis-Chalmers Manufacturing Co., are shown in figure 31. Each cabinet houses the governor heads, oil pumps, and auxiliaries for two units and a common sump tank which serves both units. The governor heads are driven by potential transformers connected to the main generator leads. The oil pumps are the screw type directly connected to 100-horsepower motors and rated at 300 gallons per minute at a pressure of 300 pounds per square inch. Each pressure tank has a volume of 530 cubic feet and the sump tank, which serves two units, has a volume of 440 cubic feet. Diagrams of the governor mechanisms at this plant are used as illustrations for chapter 4, "Governors for Hydraulic Turbines."

Generators

The generators, which are manufactured by Westinghouse Electric Corp., have a normal rating of 40,000 kilovolt-amperes, 13,800 volts, 0.9 power factor, 60 degrees centigrade rise. A single thrust and guide bearing assembly is immediately below the rotor. The thrust bearing is the Kingsbury type. Direct-connected, 250-volt direct-current main and pilot exciters are mounted above the rotor. Each generator has a closed air-circulating system with eight water-cooled radiators. A view of the generator room is shown in figure 32.

Oil systems

Three separate systems are provided at this plant to handle the different types of oil used in the transformers and circuit breakers, the generator bearing and governor system, and the runner hubs of the Kaplan turbines. These are briefly discussed as follows.

For the insulating oil a 1,200-gallon-per-hour oil purifier, consisting of a centrifuge, filter press, electric heater, and inlet and outlet pumps, is located in a separate room of the powerhouse service bay together with two oil transfer pumps, one of 100 and one of 25 gallons per minute capacity. There are six 8,000-gallon-capacity oil storage tanks—2 for dirty circuit breaker oil, 1 for dirty transformer

oil, 2 for clean circuit breaker oil, and 1 for clean transformer oil. A complete piping system connects the purification, storage, and pumping equipment with the transformers located on the intake deck, oil circuit breakers on the powerhouse roof, and the switchyard electrical equipment.

The same lubricating oil is used in the generator thrust and guide bearings which contain 3,300 gallons per unit and the governing system which contains approximately 3,350 gallons per unit. The separate purification system which handles this oil consists of a 285-gallon-per-hour centrifuge-type purifier with electric heater and inlet and outlet pumps, a 50-gallon-per-minute transfer pump, and two 8,000-gallon oil storage tanks (1 for dirty oil and 1 for clean oil). These facilities are installed in the same rooms as the insulating oil purification equipment. A 220-gallon storage tank with 100-pound-per-square-inch superimposed air pressure with a piped outlet carried to the machine shop is also provided as a source of lubricating oil for general plant use.

The oil contained in the runner hubs for lubricating the moving parts of the blade mechanism has a very high viscosity and does not require purification. When a unit is dismantled for repair or inspection, it is necessary to remove this oil from the hub. A permanent pipe header was installed from the generator room floor level down to the draft tube unwatering gallery and a section of permanent pipe was installed in each draft tube accessway. Two 970-gallon-capacity portable oil storage tanks and a 7½-gallon-per-minute, portable, screw-type pump are provided in connection with the piping system for removal of oil from the hub and for refilling. When a hub is being drained, the pump is located in the unwatering

FIGURE 32.—*Pickwick Landing generator room.*

gallery with hose connecting the pump and the runner hub drain valve to the piping system. The two portable oil tanks are temporarily located on the generator room floor level with hose connecting to the upper end of the permanent piping system. Oil is then pumped from the hub to the storage tanks. In refilling a hub the pump is simply moved to a position near the oil tanks from which oil is pumped back into the hub through the same piping system. This same type of draining and filling system is used for all the TVA Kaplan turbines. Since Pickwick was the first of TVA's Kaplan units, the two portable oil tanks and the portable oil pump were purchased for that project. Since handling of runner hub oil is an infrequent procedure, these tanks and the pump are moved from plant to plant as required for this operation.

Compressed air

A stationary air compressor having a capacity of 115 cubic feet per minute at a discharge pressure of 100 pounds per square inch, together with a 250-cubic-foot air receiver and complete piping system supplies compressed air for general station use and for operation of the generator air brakes. A portable electric-motor-driven compressor, having a capacity of 150 cubic feet per minute at 100-pound-per-square-inch discharge pressure, supplies air for maintenance of the spillway gates and for general service outside the powerhouse.

A compressed air system for draft tube evacuation was provided for motoring units 3–6. This system initially consisted of a separate 330-cubic-foot-per-minute air compressor operating at 100-pound-per-square-inch discharge pressure, six air receivers having a total storage volume of 3,500 cubic feet, and piping with solenoid-operated air valves at each unit for admission of air to the head cover for depressing tailwater level to a point below the bottom of the runner. In 1948 this system was extended to provide condensing facilities for units 1 and 2 and at that time the 330-cubic-foot-per-minute compressor was replaced with a larger compressor having a capacity of 470 cubic feet per minute at a discharge pressure of 100 pounds per square inch. The replaced compressor was transferred to Fontana Dam to augment the station air system in that plant. The kilowatt input to a Pickwick generator when motoring the unit in air varies between 700 and 800 kilowatts, and the unit can be motored with this system in approximately 1 minute.

Compressed air for the governor systems of all units is provided by a small capacity, 300-pound-per-square-inch portable compressor which superimposes air pressure on top of the oil contained in the governor accumulator tanks.

Raw water system

Each unit has a raw water intake in the scroll case, a twin strainer, and a 1,300-gallon-per-minute pump which supplies water to the generator air and oil coolers. The air cooler water is discharged back into the scroll case and the generator bearing oil cooling water is discharged directly to tailwater. There is also an intake in the forebay section with a twin strainer and a 1,300-gallon-per-minute pump which serves as a standby unit for any one of the unit cooling

water pumps. A 200-gallon-per-minute pump is also connected to the forebay system to supply raw water for air-conditioning equipment. Water for turbine bearing lubrication and the packing glands is normally supplied by gravity flow through a separate strainer taking water from the scroll case; however, an emergency cross connection with the forebay standby pump system is made. Water for the wheel pit drainage eductors for units 1 and 2 is supplied from the individual unit cooling water pumps with units 3–6 eductors being supplied by gravity flow directly from the scroll case intake. Air compressor and gasoline-engine generator cooling is supplied by gravity flow from the forebay intake system.

Treated water

Treated water for sanitary use and fire protection is supplied from the village water-treatment plant. This plant, which was built originally to supply construction and camp needs, consists of two 45- to 50-foot wells drilled on the flood plain of the south embankment, an aerator, rapid sand filter, and chlorination. Service pumps discharge water from the plant to the distribution system, a 50,000-gallon elevated storage tank in the village, and a 25,000-gallon standpipe on the north embankment. A 200-gallon-per-minute booster pump in the powerhouse supplies the 25,000-gallon tank which is used for fire protection only. Water for sanitary use in the powerhouse is drawn from the village tank system.

Sewage disposal

Sanitary waste from the powerhouse toilet fixtures discharge into a 3,000-gallon steel septic tank located in the service bay. The effluent is normally discharged by gravity directly to tailwater, but during periods of high flood it may be diverted to the station sump from which the drainage pumps will automatically discharge it to the tailrace.

Waste from the visitors' building on the south embankment and the public toilet building on the north embankment is handled in individual concrete septic tanks with subsurface tile fields.

Drainage and unwatering

All roof, deck, and floor drainage above high water levels is discharged directly to headwater or tailwater. Drainage below this level is conducted by gravity flow to two station sumps located in the service bay basement. Each sump is provided with an automatically controlled 500-gallon-per-minute pump which discharges drainage to the tailrace.

Draft tube unwatering is accomplished by two 5,000-gallon-per-minute deepwell turbine-type pumps installed in the same sumps mentioned above. Both pumps are directly connected to a 24-inch header which in turn is valved to drain inlets in each draft tube. Both pumps have auxiliary inlets with strainers which will permit their emergency use in keeping the station sumps unwatered during periods of high flood or in case of excessive leakage. The scroll cases of all units are drained directly through 16-inch valved lines to the 24-inch draft tube drain header. These same connections permit the refilling of draft tubes and scroll cases from the draft

tube of an adjacent unit. After a unit is partially refilled to tailwater level and the draft tube gates are opened, the scroll case may be completely filled by cracking the intake gates and leaving the wicket gates in closed position.

Normally the inspection galleries of the dam are drained by gravity to the station sumps. A 16-inch valved equalization line is also provided from the lower inspection gallery directly to the tailrace. During periods of high flood, this line may be opened and water allowed to rise in the gallery to tailwater level to avoid buildup of dam foundation leakage to a greater uplift pressure than tailwater pressure.

The draft tubes of the first two units at this project were each provided with a main bottom drain and an auxiliary drain inlet located on the side of the draft tube (fig. 33). During the first unwatering program it was discovered that the bottom drain inlet was completely plugged with sand and silt. As a result of this experience all additional unit draft tubes in this plant and all later designed plants are provided with single drains on the side of the draft tube which permit the draft tube to be unwatered with the exception of the bottom 18 to 24 inches. For normal inspection and maintenance the remaining water in the draft tube is of no consequence. If repairs require complete dewatering of the draft tube a construction pump is utilized to remove the small amount of water below the normal drain invert.

Fire protection

The powerhouse has four separately operated CO_2 fire protection systems. The first system serves the generators; the second serves the emergency auxiliary power generator room, the station lighting transformer room, and the auxiliary transformer bank room; the third system serves the oil purification room and the high and low station sumps; and the fourth system provides protection for the oil storage room.

In addition to portable CO_2 extinguishers located throughout the plant and switchyard, a complete water distribution system with hose racks and fire hydrants is supplied with treated water. The transformers and reactors located on the intake deck and the oil circuit breakers on the powerhouse roof are equipped with deluge-type automatically controlled water fog systems supplied with water from the 25,000-gallon north embankment treated water tank by a 1,200-

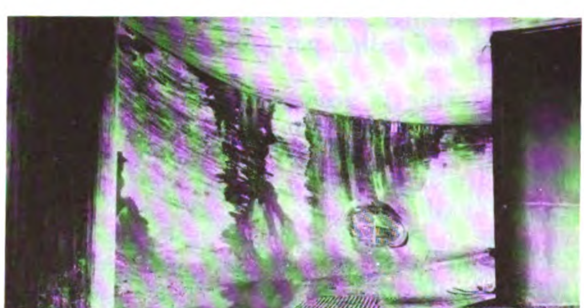


FIGURE 33.—*Pickwick Landing units 1 and 2—main and auxiliary draft tube drain inlets.*

gallon-per-minute booster pump. This system is completely described in chapter 13, "Fire Protection."

Service equipment

The machine shop, which is of conventional size and located in a separate room adjacent to the erection bay, is equipped with the machines listed in table 14, page 626.

An automatic push-button passenger elevator, having a capacity of 3,000 pounds at a speed of 250 feet per minute, serves most of the floor levels in the service bay and control building including the visitors' reception room.

The emergency auxiliary power generating unit which is installed in the service bay has a 400-kilovolt-ampere, 3-phase, 60-cycle, 480-volt, 0.8 power factor generator with direct-connected exciter driven by a 565-brake-horsepower, 8-cylinder, 1,200-revolution-per-minute gasoline engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, offices, and public spaces for the protection of electrical equipment and for human comfort. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

The air-conditioned spaces are served by a combination heating, cooling, and ventilating system complete with fan, refrigerant compressors, water-cooled condensers, electric blast heaters, cooling coils, humidifier, filters, air distribution system, and controlling devices. The two Freon compressors, each rated at 17.5 tons of refrigeration, for supplying the air-conditioning system are shown in figure 34.

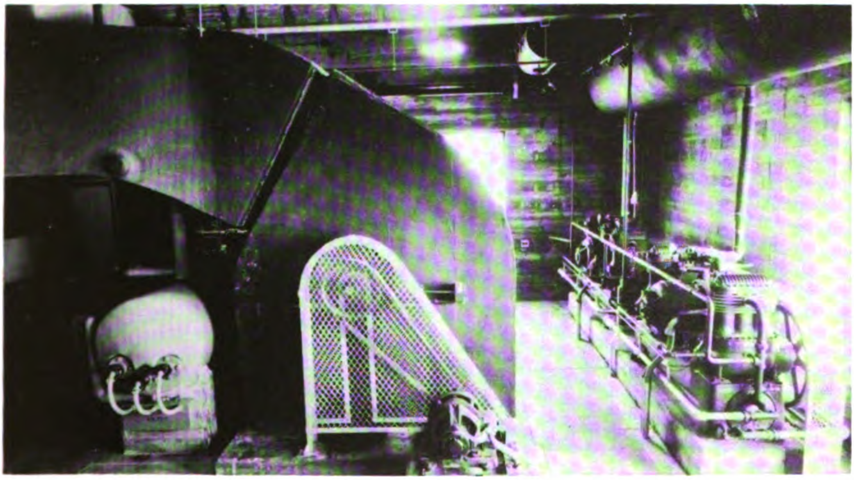


FIGURE 34.—*Pickwick Landing air-conditioning equipment room.*

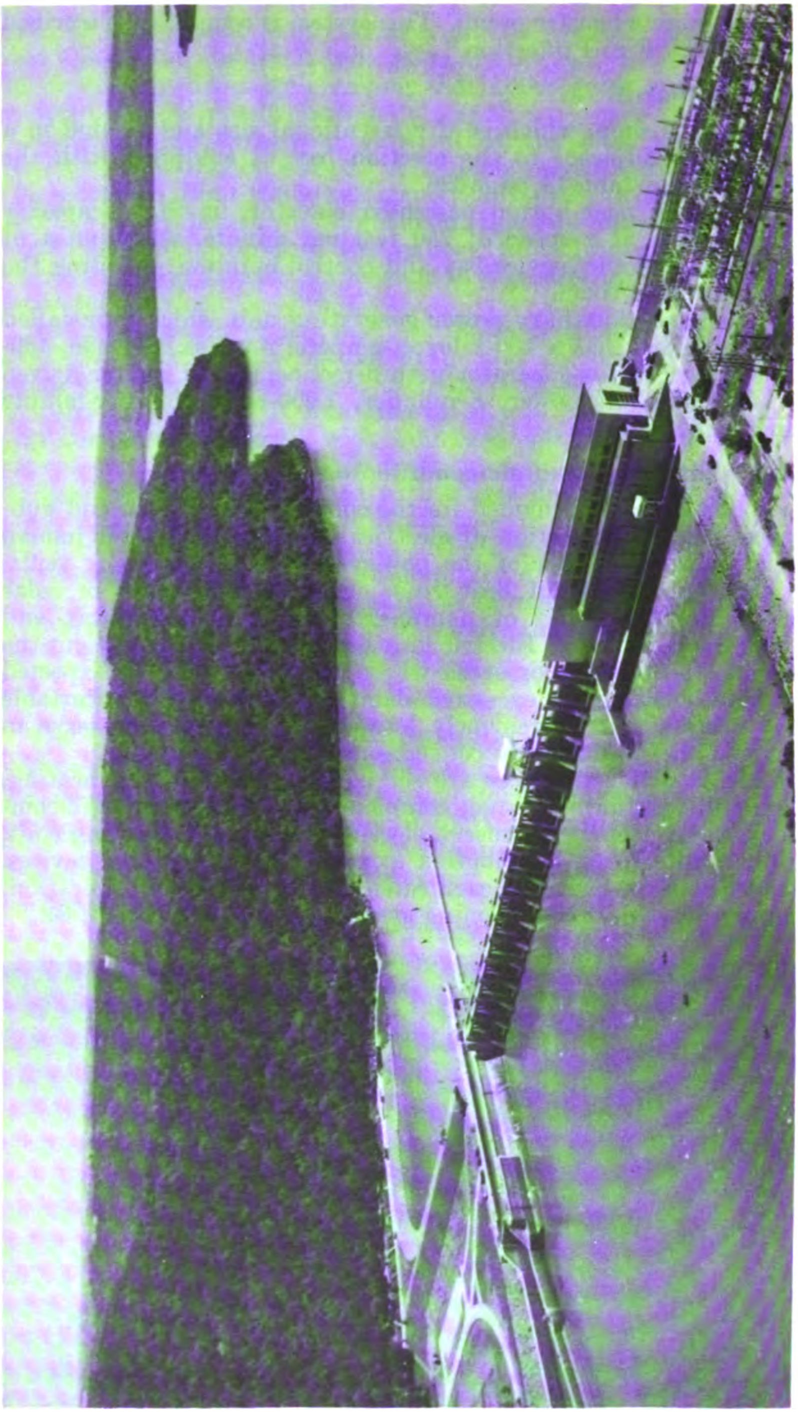


FIGURE 35.—*Guntersville project.*

GUNTERSVILLE

The Guntersville project (fig. 35) was the second designed by TVA, Pickwick Landing having been the first. Many features of the Pickwick Landing project were duplicated at Guntersville, resulting in lower design costs. Guntersville Dam is on the Tennessee River at river mile 349.0, in the State of Alabama, 74.1 miles upstream from Wheeler Dam, and 82.1 miles downstream from Hales Bar Dam. Authorization, construction, operation, and cost data are as follows:

Authorizations:	
Project and units 1, 2, and 3	November 27, 1935
Unit 4	June 28, 1949
Construction started	December 4, 1935
Closure	January 16, 1939
Commercial operation:	
Unit 1	August 1, 1939
Unit 2	October 13, 1939
Unit 3	December 26, 1939
Unit 4	March 24, 1952
Cost of the 4-unit project, including switchyard	$39,053,832

The principal structures (plan, elevation, and sections are shown in figure 9, page 23), consist of navigation lock, concrete gravity spillway section, powerhouse, and north and south rolled-fill earth embankments. The overall length of the dam is 3,979 feet, and its maximum height is approximately 94 feet from foundation to top of deck through the intake section. The spillway section extends 856 feet from the lock to the powerhouse intake and consists of 18 bays, designed for the passage of a maximum flood of 650,000 cubic feet per second. The two-section spillway gates are approximately 40 feet wide by 40 feet high and are fixed-roller, vertical lift gates, operated by two 80-ton traveling gantry cranes. The top half of one crest gate consists of three sections for operation as a trash gate.

The powerhouse section of the dam including the service bay is 386 feet long by 168 feet wide and lies between the spillway section and the south embankment. A cross section of the powerhouse is shown in figure 36.

Turbines

Four Kaplan-type hydraulic turbines manufactured by the S. Morgan Smith Co. are direct-connected to the 27,000-kilovolt-ampere synchronous generators. The turbines are rated 34,000 horsepower at a net head of 36 feet and operate at a speed of 69.2 revolutions per minute. They are designed to operate under any head from a minimum of 18 feet to a maximum of 42 feet and to withstand a maximum runaway speed of 189 revolutions per minute. At rated conditions the value of specific speed is 145 and the center line of the runner is approximately 5 feet below normal tailwater elevation giving a plant sigma of 1.05. A section of the turbine and generator is shown in figure 37.

The Guntersville units have concrete spiral cases, and stay rings are fabricated of welded steel plate. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust.

The runners have five cast steel blades set in a cast steel hub which contains the mechanism for operating the blades. Certain

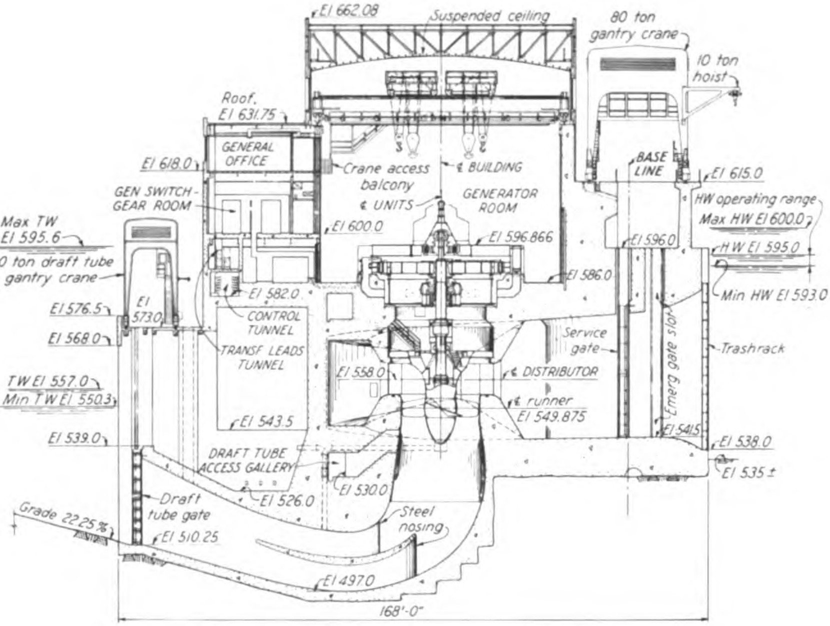


FIGURE 36.—*Guntersville powerhouse cross section.*

areas on the back side of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is guided by a water-lubricated guide bearing of molded plastic material or Insurok located above the head cover. Figure 38 shows the results of the shaft rotation check of unit 1.

In accordance with the contract, efficiency and capacity tests were made on a homologous model in the hydraulic laboratory of the turbine manufacturer. These tests indicated that the turbines would exceed the efficiency guarantees by an average of about 3 percent and would meet or exceed the capacity guarantees at all heads.

Governors

The governors are the cabinet-actuator type manufactured by the Woodward Governor Co. Units 1 and 2 governors are the twin type, mounted in a single cabinet, while units 3 and 4 are each equipped with a separate actuator cabinet. The reason for this is that only the first three units were installed originally with the fourth unit being added later.

Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for control of the turbine from the actuator. The oil pumps are the herringbone gear type with a capacity of 250 gallons per minute at 300 pounds per square inch and are driven by 60-horsepower motors. Units 1 and 2 have interconnected oil pressure systems so that both governors may be operated from one oil pump.

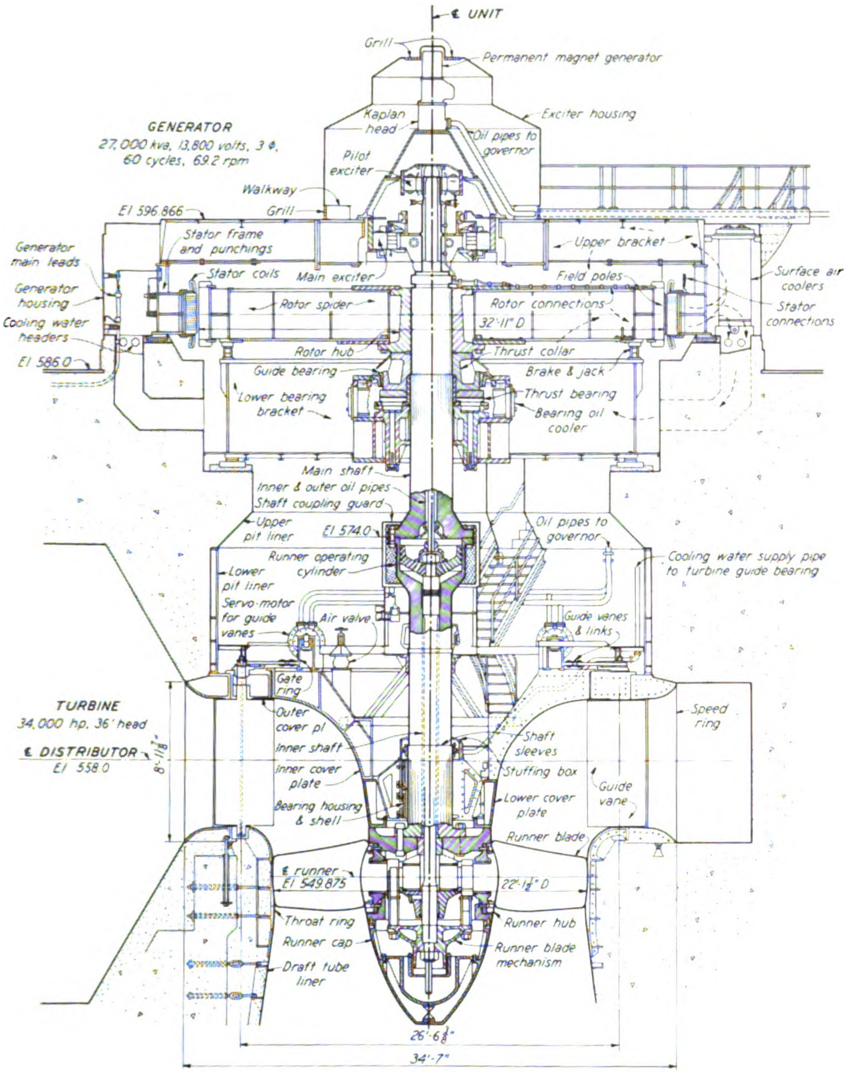


Figure 37.—*Guntersville turbine and generator section.*

Units 3 and 4 governors each have two 250-gallon-per-minute oil pumps, one of each pair operates as a spare. Each pressure tank has a capacity of 311 cubic feet. The sump tank for the twin governor has a capacity of 280 cubic feet and the sump tanks for the other two governors a capacity of 160 cubic feet each.

In 1957 equipment was added to permit remote control of the units from the plant control room.

Generators

The four generators, manufactured by the General Electric Co., have a normal rating of 27,000 kilovolt-amperes or 24,300 kilowatts

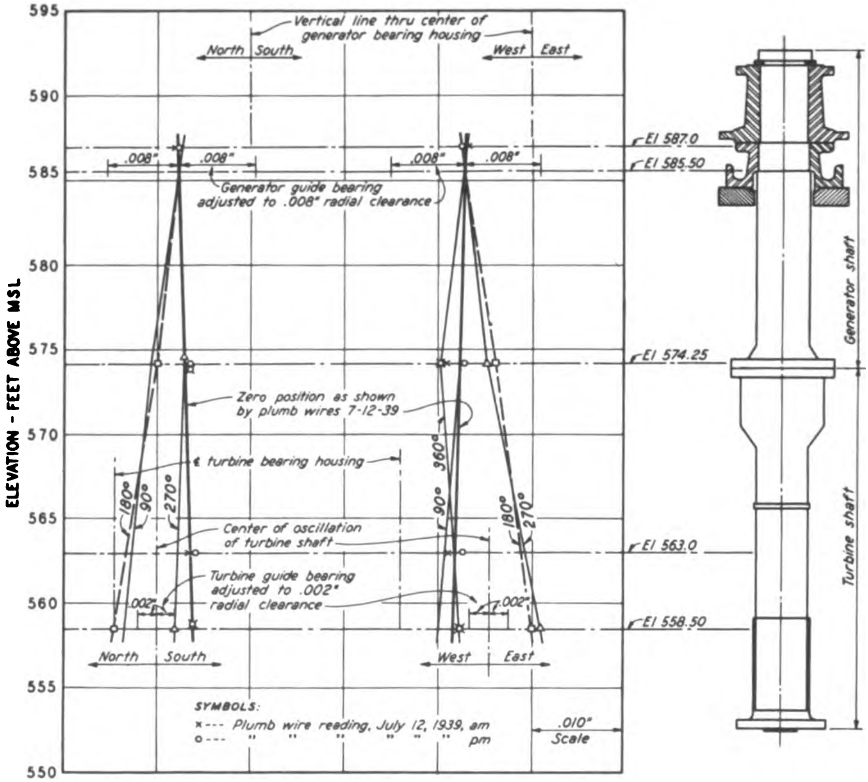


FIGURE 38.—*Results of shaft rotation check—Guntersville unit 1.*

at 0.9 power factor and 13,800 volts. The main and pilot exciters are mounted above the main rotor. An enclosed, water-cooled air-circulating system and CO_2 fire protection are provided. A combination thrust and guide bearing is located below the rotor in an oil reservoir having a capacity of 1,400 gallons for units 1, 2, and 3 and 2,000 gallons for unit 4.

Units 1, 2, and 3 are equipped with a Kingsbury-type thrust bearing, and unit 4 has the General Electric type. The generators are of the indoor type as shown in figure 39.

Oil systems

The governor and lubricating oil system includes one 300-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 3,000-gallon capacity; and connecting piping.

The transformer and circuit breaker oil system in the switchyard includes an oil purification building which houses a 600-gallon-per-hour purifier and 1 clean- and 1 dirty-oil pump, each of 100-gallon-per-minute capacity. Two 6,450-gallon insulating oil storage tanks are located on each side of the purification building, providing storage capacity of 12,900 gallons for dirty transformer oil, 6,450 gallons for dirty circuit breaker oil, and 6,450 gallons for clean insulating oil.

A fixed piping system for filling and emptying the runner hubs is also installed in the powerhouse.

Compressed air systems

A stationary single-stage, double-acting air compressor in the service bay provides compressed air for station service and generator air brakes. The compressor has a capacity of 105 cubic feet per minute at 100 pounds per square inch. The system includes a water-cooled aftercooler, a 150-cubic-foot receiver, and a complete piping system with service outlets. Compressed air is also supplied by this system to the unit grease compressors, forging furnace, and the hydropneumatic raw water tank.

An air system is provided for vibration dampening for units 1, 2, and 3 and for operation of units 1 and 2 as synchronous condensers. The system consists of an air compressor rated at 470 cubic feet per minute and 100 pounds per square inch; an aftercooler; three air receivers with a total capacity of 2,700 cubic feet; and float controlled, solenoid-operated valves for automatic regulation of the depressed water level in the draft tube. Excessive vibration when generating with units 1, 2, and 3 was greatly reduced by admission of air to the draft tube throat. The draft tube evacuation system is described in some detail in chapter 7.

A 300-pound-per-square-inch governor compressed air system is also in the powerhouse.

Raw water system

The normal unit cooling water supply is obtained from intakes in each unit scroll case, strained, and pumped through the generator air and oil coolers by the 1,300-gallon-per-minute unit cooling water pumps, and discharged back to the scroll case. An emergency, 1,300-gallon-per-minute cooling water pump in the service bay, with two raw water intakes in the forebay, serves as a standby.

To eliminate excessive turbine bearing wear, which developed soon after initial operation, it was found necessary to filter the turbine water supply. This was done with the addition of three pressure sand filters, a 450-gallon-per-minute filter service pump, a 750-gallon-

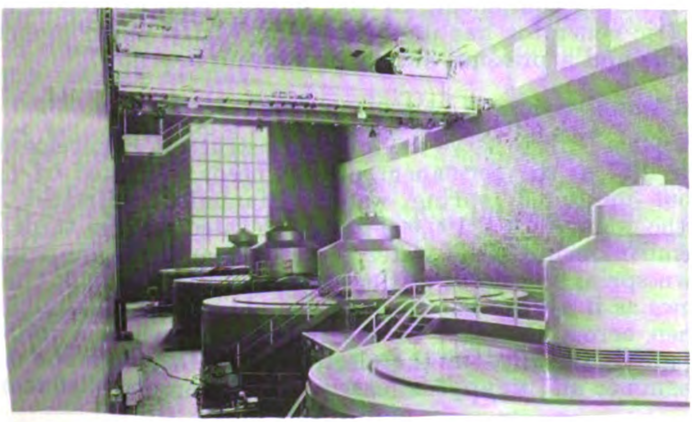


FIGURE 39.—*Guntersville generator room.*

per-minute filter backwash pump, located in the service bay, with intakes in the forebay, and connecting piping. The filters have not been necessary for several years but they are kept in standby condition.

During the alterations made in 1957 for remote control of the turbines, the manually operated valves controlling the flow of cooling water to the generator air coolers were replaced with two air-operated diaphragm proportioning valves, installed in echelon. Flow is controlled by temperature sensitive bulbs located within the generator housings which operate temperature regulators for controlling the flow of loading air to the proportioning valves' diaphragm motors. This effects a constant temperature within the generator housing regardless of load being carried. Limit switches on the extreme open and closed positions of each valve operate indicating lights in the control room to show the operators the approximate throttled condition. The flow to the generator bearing cooling water system is controlled by manually throttled valves from the pumped supply. The flow to the turbine bearing is similarly controlled but normally by gravity flow from its own scroll case and through its own duplex strainer with discharge to its draft tube. In an emergency, turbine bearing water may be obtained by gravity from dual intakes in the service bay or from the filtered water supply described previously.

Flowmeters with low flow alarm contacts are installed in the supply pipes to the generator air coolers, generator bearing oil coolers, and turbine bearings. These actuate alarms in the control room on low flow and shut down the unit in case of extreme low flow to the turbine bearing or generator bearing oil coolers. Need for cleaning the raw water strainers is made known to the operators by alarms controlled by differential pressure switches installed across the strainers.

The two forebay raw water intakes also supply two 300-gallon-per-minute fire and service pumps in the service bay. A 2,000-gallon capacity hydropneumatic storage tank provides a pressure of 82 pounds per square inch for station service, fire protection in the powerhouse and switchyard, and lawn sprinkling.

Gravity flow from the forebay intakes supply raw water to the air-conditioning equipment, air compressors, and aftercoolers. The gas-electric generator has its own cooling water pump mounted on the engine and a pressure switch to indicate low flow.

Treated water system

The system built to serve the initial construction requirements, and through 1957 as the permanent project needs, consisted of chlorinated, but unfiltered, spring water. Manually controlled pumps raised the water into a 100,000-gallon elevated storage tank on the north embankment. This water serves all sanitary, fire-protection, and lawn sprinkling needs at the project. From the tank the water now flows as it always has through the old village distribution system, then across the dam to the powerhouse where a 200-gallon surge tank is installed in the electrical bay to reduce shock from water hammer and to approximate equal pressure on all fixtures.

Occasionally the spring discharges turbid water, at which times the operator could not pump even though the tank level was down. This resulted in an inadequate fire-protection system and in 1957 design was completed for a more reliable water supply. The same spring water flows by gravity to a receiving well where low lift vertical pumps raise it to two slow sand filters having a combined capacity of 15 gallons per minute. The effluent flows by gravity to the clearwell of the original plant where the old pumps, now on float switch control in the elevated tank, automatically pump water as dictated by the elevated tank level. The original chlorinator was also converted to automatic control so that water leaving the plant is sterilized.

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse discharges into a 2,860-gallon steel septic tank located at elevation 568 in the service bay. Under normal conditions of tailwater the effluent from the tank discharges into the tailrace by gravity through an outlet at elevation 547.5. When tailwater rises above elevation 568.0 the effluent from the tank is diverted to the station sump from which it will be automatically discharged to tailwater by the drainage pumps.

The sanitary waste from the toilet facilities in the public toilet building on the south embankment discharges into a 5,000-gallon concrete septic tank located 38 feet northwest of the building. The septic tank is provided with a siphon and the effluent discharges into a subsurface tile field with 6-inch underdrains terminating in gravel fill under the riprap of the tailrace at elevation 576.

The sanitary waste from the toilet facilities in the lock operation building drains directly into the tailrace through a 6-inch pipe terminating at elevation 549.

Drainage and unwatering

All station drainage, except the powerhouse roof drains which empty into the tailrace, is discharged into the station drainage sump in the basement of the service bay. The sump has a capacity of 9,665 gallons to the overflow level with an overflow connection to the draft tube unwatering sump. Two 300-gallon-per-minute, float-operated, turbine-type pumps deliver water from the station drainage sump into the tailrace.

The draft tube sump, which is located in the powerhouse substructure between units 2 and 3, is unwatered by two 5,000-gallon-per-minute, manual-operated, deepwell, turbine-type pumps. A 16-inch drain with a control valve connects each draft tube to the sump, and a 16-inch scroll case drain to the draft tube is provided at each unit. One unwatering pump will drain a draft tube in approximately 3 hours.

Fire protection

Three CO_2 fire-protection systems are provided, each system having three means of controlling the release of the gas: by thermostat, by

manual-electric break-glass control boxes, and by manual release at the CO_2 cylinders. One system is for generator protection, one protects the gasoline-engine generator room and lubricating oil handling equipment in the powerhouse, and the third system protects the oil purification building in the switchyard. Numerous portable CO_2 extinguishers are located about the powerhouse and switchyard.

General fire protection within the powerhouse and for the transformers and electrical equipment in the switchyard is supplied from the raw water system. The equipment includes four 4-inch fire hydrants and numerous hose outlets, fire hose reels, and two 300-gallon-per-minute raw water pumps operating in conjunction with the automatically controlled hydropneumatic tank system previously mentioned.

Service equipment

The machine shop, which is conventional size and located in a separate room in the service bay adjacent to the generator room, contains the equipment listed in table 14, page 626.

The emergency auxiliary power generating unit which is installed in the service bay has a 300-kilovolt-ampere, 3-phase, 60-cycle, 480-volt generator with direct-connected exciter driven by a 425-brake-horsepower, 6-cylinder, 1,200-revolution-per-minute gasoline engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, telephone room, first-aid room, laboratory, and offices for the protection of electrical equipment and for human comfort. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters strategically located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

For flexibility of control, the air-conditioning spaces are served by two combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling, coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system.

A summary of the ventilating, heating, and air-conditioning requirements is as follows:

Cubic feet per minute of air supplied and exhausted	211,000
Kilowatts of installed electric heating	292
Horsepower of refrigeration	40

CHICKAMAUGA

The Chickamauga project (fig. 40) extends the navigable channel on the Tennessee River from the headwaters of Hales Bar Reservoir to the site of Watts Bar Dam. Chickamauga Dam is at river mile 471.0 in Hamilton County, Tenn., and is approximately 6.8 river miles

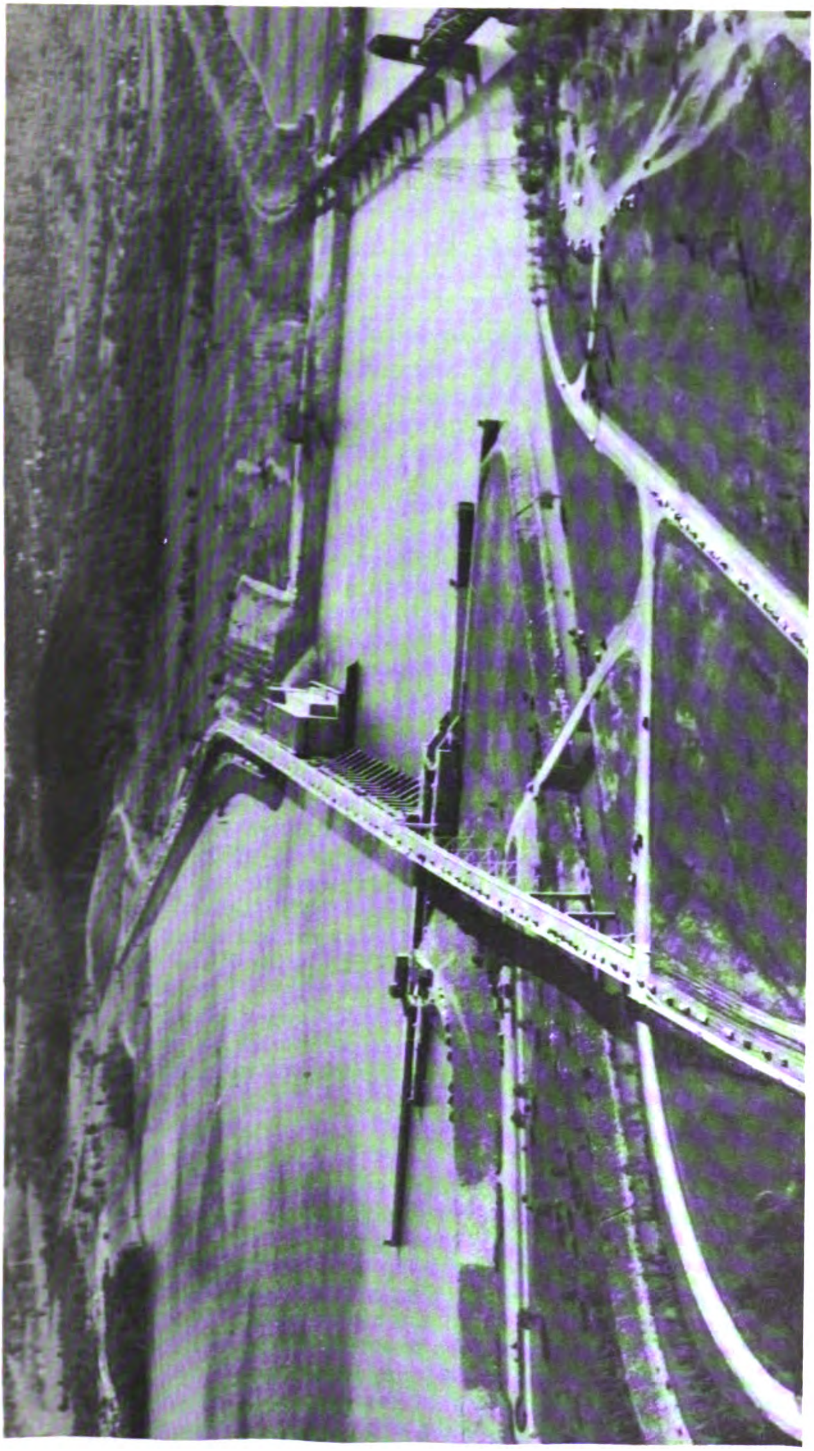


FIGURE 40.—*Chickamauga project.*

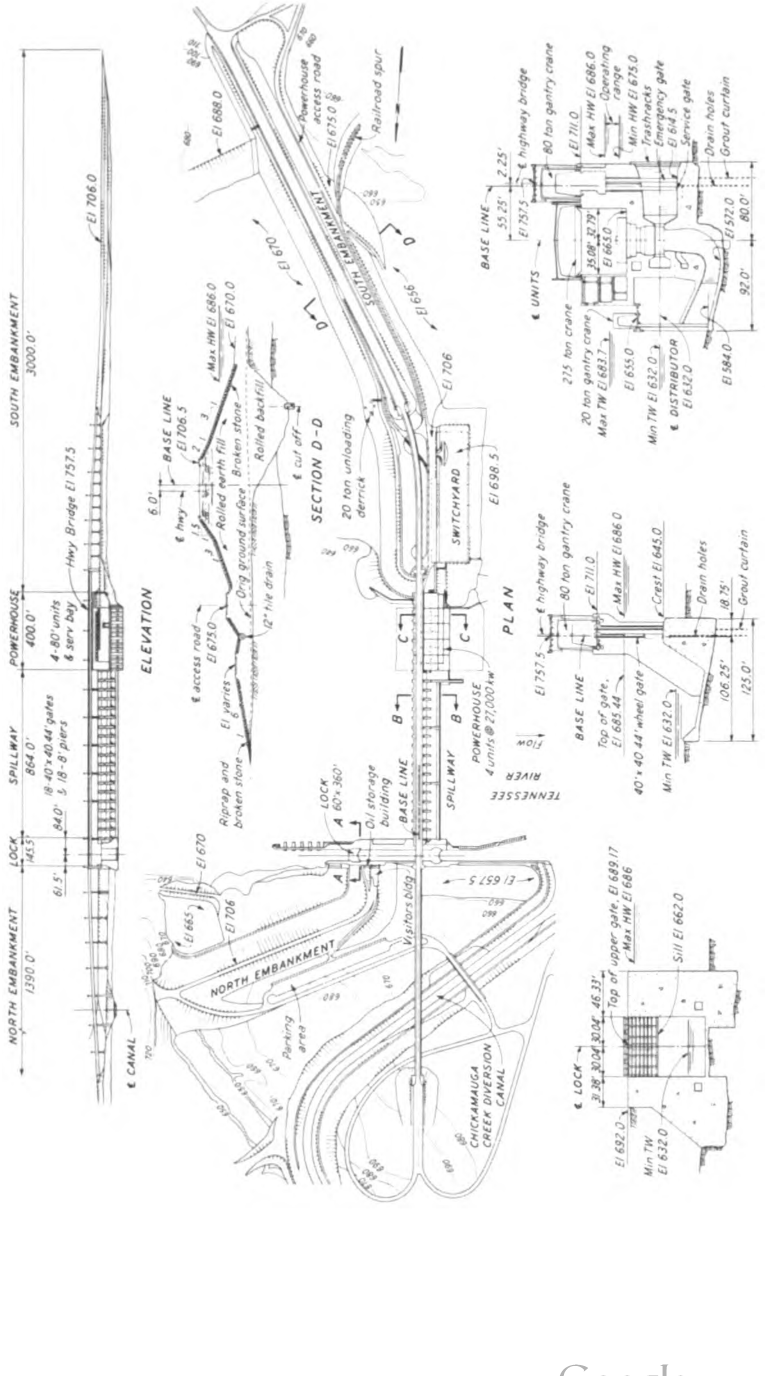


FIGURE 41.—*Chickamauga—plan, elevation, and sections.*

above Chattanooga, Tenn. It is situated 39.9 miles upstream from Hales Bar Dam and 58.9 miles downstream from Watts Bar Dam. Authorization, construction, operation, and cost data are as follows:

Authorizations:	
Project and units 1, 2, and 3	December 31, 1935
Unit 4	June 28, 1949
Construction started	January 13, 1936
Closure	January 15, 1940
Commercial operation:	
Unit 3	March 4, 1940
Unit 2	May 2, 1940
Unit 1	July 15, 1940
Unit 4	March 7, 1952
Cost of the 4-unit project including switchyard	$40,624,617

The completed structure consists of a navigation lock, concrete gravity spillway section, and powerhouse, flanked on both north and south by rolled-fill earth embankments (fig. 41). The highway bridge over the dam, designed by TVA for the State of Tennessee and the U.S. Bureau of Public Roads, was built in 1953–54. The over-all length of the dam is 5,800 feet, and its maximum height is 129 feet from foundation to the deck of the intake section. The concrete spillway section extending from the river wall of the lock to the powerhouse intake, a distance of 864 feet, is made up of 18 bays, designed for the passage of a maximum flood of 685,000 cubic feet per second. The spillway gates are the fixed roller vertical-lift type in two sections and are nominally 40 feet wide by 40 feet high. They are operated by either of two 80-ton-capacity gantry cranes located on the operating deck of the spillway.

The powerhouse section lies between the spillway and the south embankment. The outdoor switchyard is adjacent to the powerhouse on a downstream projection of the earth embankment.

The powerhouse structure (fig. 42) is the indoor type and is 400 feet long, consisting of intake, electrical bay, generator room, and service bay. The intake structure is composed of three bays for each of four units. Two sets of interchangeable, structural steel, vertical lift gates are provided. The intake gates are operated by either of the spillway gantry cranes. Draft tube gates are vertical lift, slide gates 18 feet wide by 26 feet high. These are operated by a 20-ton-capacity gantry crane operating on the draft tube deck.

Design work on Guntersville and Chickamauga projects was carried on essentially at the same time and in many respects the projects are quite similar.

Turbines

Four Kaplan-type hydraulic turbines manufactured by the Baldwin-Lima-Hamilton Corp. are direct-connected to the 30,000-kilovolt-ampere synchronous generators (fig. 43). The turbines are rated 36,000 horsepower at a net head of 36 feet and operate at a speed of 75 revolutions per minute. They are designed to operate under any head from a minimum of 20 feet to a maximum of 52 feet and to withstand a maximum runaway speed of 231 revolutions per minute. At rated conditions the value of specific speed is 161, and the centerline of the runner is approximately 9 feet below normal tailwater elevation giving a plant sigma of 1.21.

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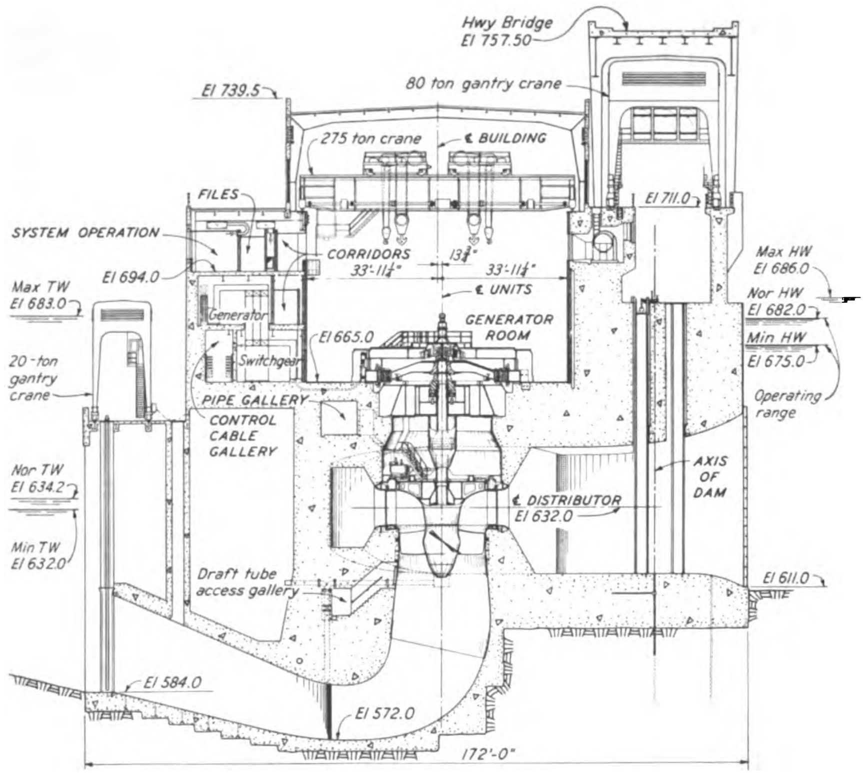


Figure 42.—*Chickamauga powerhouse cross section.*

The Chickamauga units have concrete spiral cases with cast-steel stay rings. The stayrings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners have five cast-steel blades set in a cast-steel hub which contains the mechanism for operating the blades. Certain areas on the back side of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is guided by a water-lubricated guide bearing of molded plastic material or Insurok located in the bore of the head cover barrel.

Efficiency acceptance tests were made at the manufacturer's hydraulic laboratory on a homologous model. These tests indicated that the prototype would exceed the efficiency guarantees by an average of more than 3 percent and would meet or exceed the capacity guarantees at all heads.

Governors

The governors are the cabinet-actuator type manufactured by the Woodward Governor Co. Units 2 and 3 governors are the twin type, mounted in a single cabinet, while units 1 and 4 are each equipped with a separate actuator cabinet. The reason for this is that only the first three units were installed originally with the fourth unit being added later.

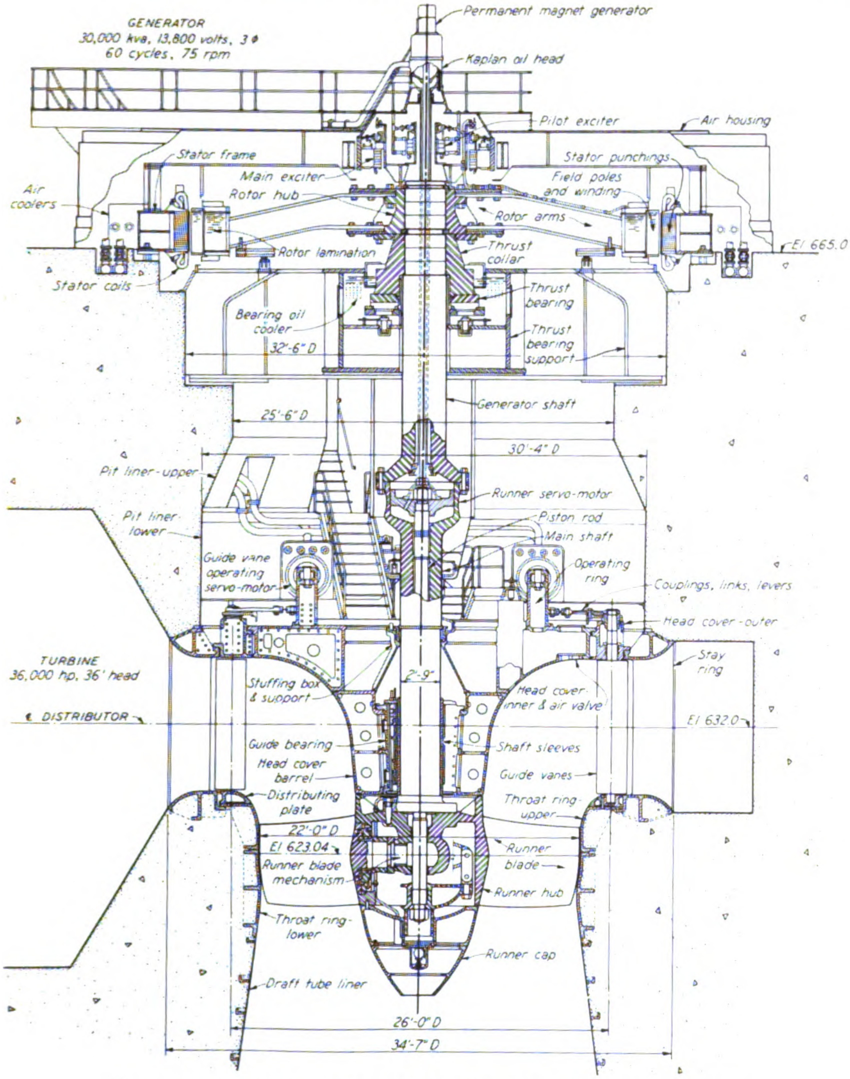


FIGURE 43.—*Chickamauga—section through turbine and generator.*

Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for control of the turbine from the actuator. The oil pumps are the herringbone-gear type with a capacity of 275 gallons per minute at 300 pounds per square inch and are driven by 75-horsepower motors. Units 2 and 3 have interconnected oil pressure systems so that both governors may be operated from one oil pump. Units 1 and 4 governors each have two 275-gallon-per-minute pumps, one of each pair operates as a spare. Each pressure tank has a capacity of 350 cubic feet. The sump tank for the twin governor has a capacity of 312 cubic feet and the sump tanks for the other two governors each have a capacity of 195 cubic feet.

In 1957 equipment was added to provide for remote control of the units from the plant control room.

Generators

The four generators, manufactured by the Allis-Chalmers Manufacting Co., are rated 13,800 volts, 3 phase, 60 cycle, 30,000 kilovolt-amperes, 27,000 kilowatts, and 0.9 power factor. The exciters are direct-connected above the rotor, the pilot exciter being partially telescoped within the main exciter. Figure 43 shows a section of the generator.

Heat losses within the generator are removed by forced-air circulation through eight coolers in the generator air housing. The air is cooled to 40 degrees centigrade or lower when the cooling system is supplied with a maximum of 1,000 gallons per minute of 30-degree centigrade water. The fire-protection system provides an initial and delayed discharge of carbon dioxide for the estimated 14,000 cubic feet of air space within the generator.

Each generator has a set of eight single-cylinder units of combined air-operated brakes and oil-operated jacks mounted on the bearing bracket arms, designed for 100-pound-per-square-inch air pressure and for 3,300-pound-per-square-inch oil pressure. The Kingsbury thrust and guide bearings are immersed in a common oil reservoir which holds 2,150 gallons of oil. Cooling coils in the oil reservoir were designed to pass 100 gallons per minute of 30-degree centigrade water.

The generators are the indoor type as shown in figure 44.

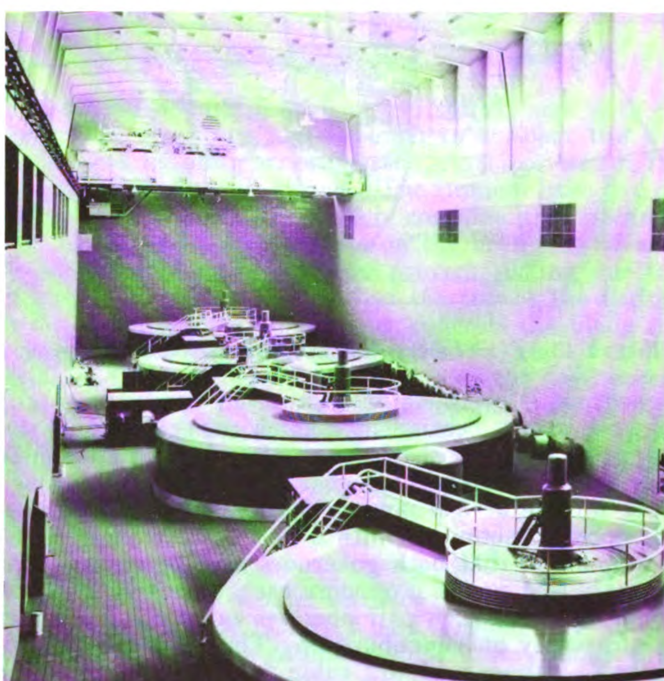


Figure 44.—*Chickamauga generator room.*

Oil systems

The governor and lubricating oil purification system consists of one 300-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 3500-gallon capacity; and the necessary connecting piping. The purifier and tanks are in the service bay.

Also in the service bay are the storage tanks, pump, and purification equipment for the transformer and circuit breaker insulating oil system. The oil storage facilities consist of 1 clean and 1 dirty transformer oil tank, each of 8,500-gallon capacity, and 1 clean and 1 dirty circuit breaker oil tank, each of 5,600-gallon capacity. One 100-gallon-per-minute clean oil pump is provided for filling the electrical equipment in the switchyard by means of hose connections from convenient valve boxes. The equipment is drained by gravity through the drain header. The insulating oil purifier has a capacity of 600 gallons per hour without the press and 900 gallons per hour with the filter press.

A fixed piping system for filling and emptying the runner is also installed in the powerhouse.

Compressed air systems

A stationary single-stage double-acting air compressor with a capacity of 105 cubic feet per minute at 100 pounds per square inch in the service bay supplies station service and generator brake air requirements. A complete piping system with service outlets is provided, with connections to the fire and service water pressure tank and the forging furnace. The system includes a 160-cubic-foot-capacity air receiver and a water-cooled aftercooler. Air pressure in the system is automatically maintained by a pressure governor.

Compressed air for the unit governor systems is supplied by an 8-cubic-foot-per-minute portable compressor operating at 300 pounds per square inch.

Units 1 and 2 together have a single complete draft tube evacuation system to allow these units to be operated as synchronous condensers, and provision has been made for a future similar installation at units 3 and 4. The system includes a 470-cubic-foot-per-minute draft tube evacuation air compressor discharging at 100 pounds per square inch, a water-cooled aftercooler, four air receivers with a total volume of 2520 cubic feet, and a piping system with float-controlled, solenoid-operated valves for automatic regulation of the depressed water level in the draft tubes of units 1 and 2.

Raw water system

Normal unit cooling water supply is obtained from intakes in each unit scroll case, strained, and was originally pumped through the generator air and oil coolers by 1,100-gallon-per-minute unit cooling water pumps, and discharged back to the scroll case. An 1,100-gallon-per-minute emergency cooling water pump was located in the service bay with two raw water intakes in the forebay to serve as a standby.

During alterations made in 1957 to control the turbines remotely, new 1,400-gallon-per-minute cooling water pumps replaced the original 1,100-gallon-per-minute units, and two air-operated diaphragm

proportioning valves, installed in echelon, replaced the original manually operated valves for controlling the flow of cooling water to the generator air coolers. Flow of cooling water to maintain a constant air temperature within the generator housing is controlled by temperature sensitive bulbs, located in the air stream from the coolers inside the housing, which operate temperature regulators for controlling the flow of loading air to the proportioning valves diaphragm motors. Limit switches on the extreme open and closed positions of each valve stem operate indicating lights in the control room and show the approximate throttled condition. The flow to the generator bearing cooling water system is controlled by manually throttled valves from the pumped supply. The flow to the turbine bearing is similarly controlled but flow is by gravity from its own scroll case and through its own duplex strainer with discharge to its draft tube. In an emergency, turbine bearing water may be obtained by gravity from dual intakes in the service bay.

Flowmeters with low flow alarm contacts are installed in the supply pipes to the generator air coolers, generator bearing oil coolers, and turbine bearings. These actuate alarms in the control rooms on low flow and shut down the unit in case of extreme low flow to the turbine bearing or generator bearing oil coolers. Need for cleaning the raw water strainers is called to the operator's attention by alarms actuated by differential pressure switches installed across the strainers.

The two forebay raw water intakes also supply two 300-gallon-per-minute fire and service water pumps in the service bay, which discharge into a separate station raw water system. A 2,000-gallon-capacity hydropneumatic storage tank maintains a pressure of 90 pounds per square inch in the system for station service, fire protection in the powerhouse and switchyard, and lawn sprinkling. Gravity flow from the above intakes provide strained cooling water to the gas-electric generator, and by means of an 8-inch pump bypass, also to the air compressors, aftercoolers, and air-conditioning equipment.

Treated water system

All treated water for the powerhouse and lock is purchased from the city of Chattanooga water system. The water flows from the city mains, a distance of approximately 2.3 miles to the project or 8 miles from the city reservoir, to a point near the switchyard on the south embankment where a pressure reducing valve is installed. The line continues to a second pressure reducing valve in the powerhouse on the elevation 649 floor at which the pressure is reduced to 54 pounds per square inch. A 2,000-gallon surge and storage tank on the elevation 726 floor of the powerhouse maintains a relatively constant pressure on the supply line. The extension of the main from the city system was installed during the initial project construction.

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse discharges into a 3,300-gallon steel septic tank located at elevation 649 in the service bay. Under normal conditions of tailwater the effluent from the tank drains directly into the tailrace by gravity

through an outlet at elevation 627.44 in unit 1 draft tube pier. When tailwater rises above elevation 649 the effluent from the tank is diverted to the station sump where it will be automatically discharged to tailwater by the drainage pumps.

The sanitary waste from the toilet facilities in the visitors' building on the north abutment discharges into a 3,700-gallon concrete septic tank located approximately 135 feet west of the building. The effluent from the tank discharges into a dry well.

The sanitary waste from the toilet facilities in the lock operation building drains directly into the tailrace at elevation 627 at the downstream end of the lock.

Drainage and unwatering

Most of the powerhouse drainage is discharged into the station sump in the basement of the service bay. It is pumped from there to the tailrace. The sump has a capacity of 11,200 gallons to the overflow level, with a 15-inch overflow connection to the draft tube unwatering sump. It is serviced by two 300-gallon-per-minute turbine-type pumps with 10-horsepower vertical motors mounted on the basement floor of the service bay. Operation of the pumps is automatically controlled by float switches.

The turbine pit is unwatered by a 1-inch jet eductor. The discharge from the eductor is carried in a 4-inch pipe to a trench in the draft tube access gallery, and then to the station drainage sump.

It was necessary to provide means for unwatering the draft tubes and scroll cases to allow access to the turbine because the runner is below normal tailwater. The draft tube for each unit was therefore provided with a screened outlet 2 feet above the low point of the draft tube. A 16-inch drain with a control valve connects each draft tube to the unwatering sump which is located between units 2 and 3. The scroll case and draft tube of each unit are also connected to each other and to tailwater by a 16-inch line. The drain valves for all units are operated from the pump room and the pipe gallery.

Two 5,000-gallon-per-minute deepwell turbine-type pumps are installed for unwatering the sump. Each pump is operated by a 200-horsepower motor mounted on the floor of the pipe gallery. The pumps are manually controlled.

Fire protection

Three separate CO_2 fire-extinguishing systems are each arranged for local manual or automatic remote control.

The fire-protection system for the generators consists of an initial discharge bank of twenty-four 50-pound cylinders of CO_2 and a delayed discharge bank of 12 cylinders, located in the CO_2 room. The gas is released and routed automatically to any generator by operation of the generator differential relay, the generator neutral overcurrent relay, or any of the eight thermostatic switches within the housing air ducts. Release and routing can also be accomplished manually at the CO_2 equipment, or by a control switch on the actuator panel.

The second system protects the oil storage room and consists of twenty 50-pound CO_2 cylinders with control equipment for simultaneous discharge. The third system consists of a bank of ten

50-pound CO_2 cylinders arranged for simultaneous discharge into either the oil purification room or the gas-electric generator room.

Numerous portable fire-extinguishing units are conveniently located in the powerhouse and switchyard. Two 100-pound, buggy-type CO_2 units in separate fire equipment buildings are in the switchyard, one near the main transformer bank and the other between the 161- and the 46-kilovolt switchyards.

General fire protection within the powerhouse and for the transformers and electrical equipment in the switchyard is supplied from the raw water system. The equipment includes two 300-gallon-per-minute pumps, a 2,000-gallon hydropneumatic storage tank, three 4-inch fire hydrants, and numerous fire hose racks.

Service equipment

The machine shop, which is conventional size and located in a separate room in the service bay adjacent to the generator room, contains the equipment listed in table 14, page 626.

An automatic push button-controlled elevator, having a live load capacity of 5,000 pounds at a speed of 250 feet per minute, is in the service bay for the use of operating personnel and visitors. The elevator serves all operating floor levels and the visitors' lobby. Design data covering this machine are included in table 6, page 394.

The emergency auxiliary power generating unit which is installed in the service bay has a 300-kilovolt-ampere, 0.8 power factor, 3-phase, 60-cycle, 480-volt generator, with direct-connected exciter driven by a 425-brake-horsepower, 6-cylinder, 1,200-revolution-per-minute gasoline engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, public spaces, and offices for the protection of electrical equipment and for human comfort. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters strategically located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

For flexibility of control, the air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system. A packaged air-conditioning unit serves the office in the unit 4 area.

A summary of the ventilating, heating, and air conditioning requirements for this project is as follows:

Cubic feet per minute of air supplied and exhausted	369,900
Kilowatts of installed electric heating	534
Horsepower of refrigeration	105

HIWASSEE

Hiwassee Dam (fig. 45), named for the river on which it is located, is the second tributary storage dam constructed by TVA. The Hiwassee Reservoir, 112 river miles above Chattanooga in the State of North Carolina, is especially effective in reducing high flood stages in the valley and particularly at Chattanooga. In addition, its controlled storage volume is usable for the regulation of navigation channel depths, for power generation, and for malaria control in the downstream system.

The Hiwassee project is unique in that the second unit is a reversible pump-turbine unit designed to utilize low cost power from the system during offpeak load periods to pump water from Apalachia Reservoir to storage in the Hiwassee Reservoir for use during peak load periods.

Authorization, construction, operation, and cost data are as follows:

Authorizations:	
Project and unit 1	January 10, 1936
Unit 2	September 25, 1951
Construction started	July 15, 1936
Closure	February 8, 1940
Commercial operation:	
Unit 1	May 21, 1940
Unit 2	May 24, 1956
Cost of the 2-unit project including switchyard	$23,151,942

The Hiwassee Dam is a straight gravity-type concrete overflow structure (fig. 46). Along its 1,287-foot crest length, a 19-foot roadway serves both as a highway crossing and as the spillway operating bridge. A 260-foot-long overfall spillway occupies the river channel position and is 307 feet high from the lowest excavation on the axis of the dam to the roadway level. On either side of the spillway, nonoverflow sections extend to the abutment slopes. The powerhouse is located along the toe of the dam at the left bank, and the adjacent switchyard is constructed on terraces cut from the hillside.

Water may be discharged through any or all four sluiceway conduits in the bottom of the spillway. On the spillway crest are mounted seven radial gates 23 feet high and 32 feet long for the discharge of 127,000 cubic feet per second under maximum headwater conditions.

The Hiwassee powerhouse is the semioutdoor type, approximately 182 feet long and 140 feet wide, with a 275-ton-capacity gantry crane mounted on the roof of the generator room. The electrical bay is upstream from the units. The powerhouse cross section for unit 1 is shown in figure 47 and for unit 2 is shown in figure 48.

Turbines

The turbine installed in unit 1 is the vertical Francis type manufactured by the Newport News Shipbuilding & Dry Dock Co. and is identical to the Norris turbines except that it is rated at a higher head and operates at a higher speed. It is direct-connected to a 64,000-kilovolt-ampere synchronous generator. The turbine is rated 80,000 horsepower at a net head of 190 feet and operates at a speed

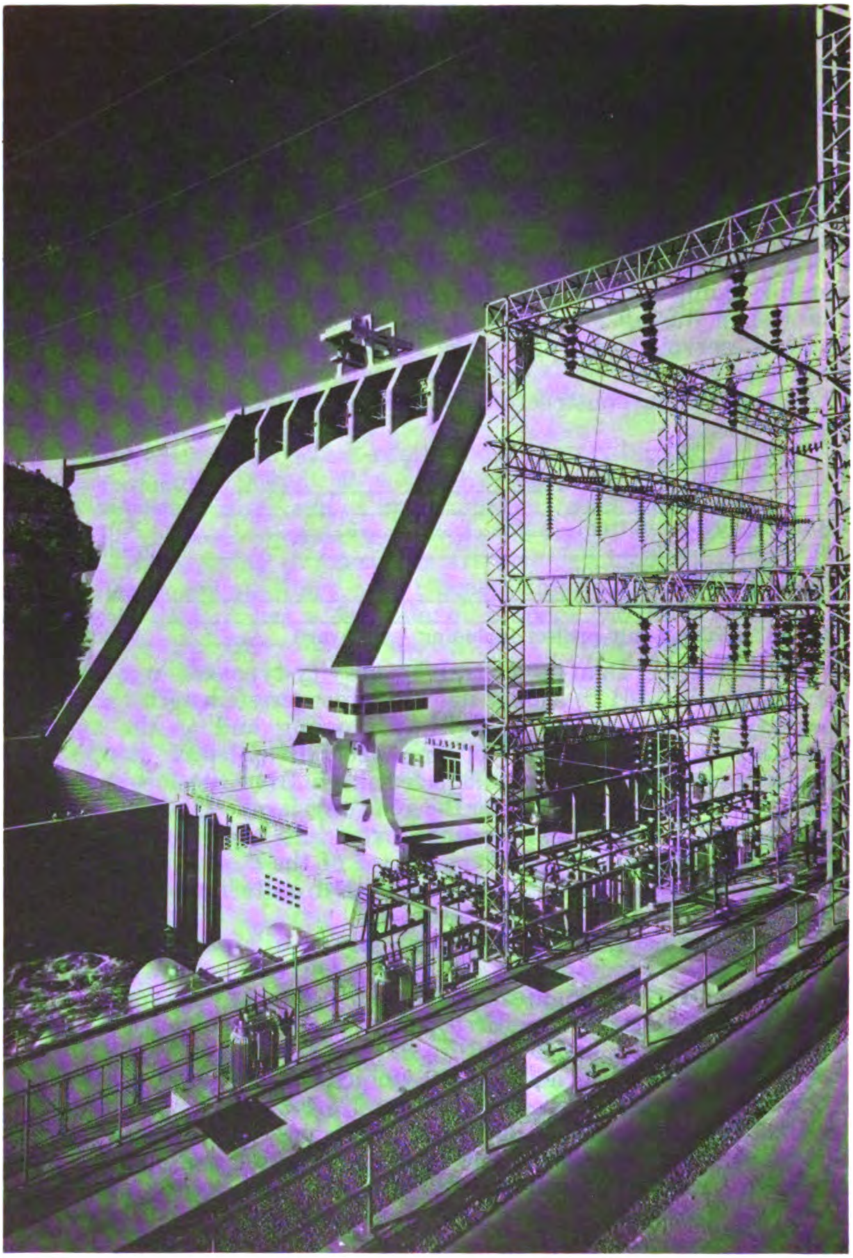


FIGURE 45.—*Hiwassee project before installation of unit 2 pump-turbine.*

of 120 revolutions per minute. It is designed to operate satisfactorily under any head from a minimum of 142 feet to a maximum of 245 feet and is most efficient at a net head of about 200 feet. It is also designed to withstand a maximum runaway speed of 235 revolutions per minute. At rated conditions the value of specific speed is 48, and the center line of the runner is placed about 4 feet above normal tailwater elevation giving a plant sigma of 0.14. Figure 49 shows a section of the unit 1 turbine and generator.

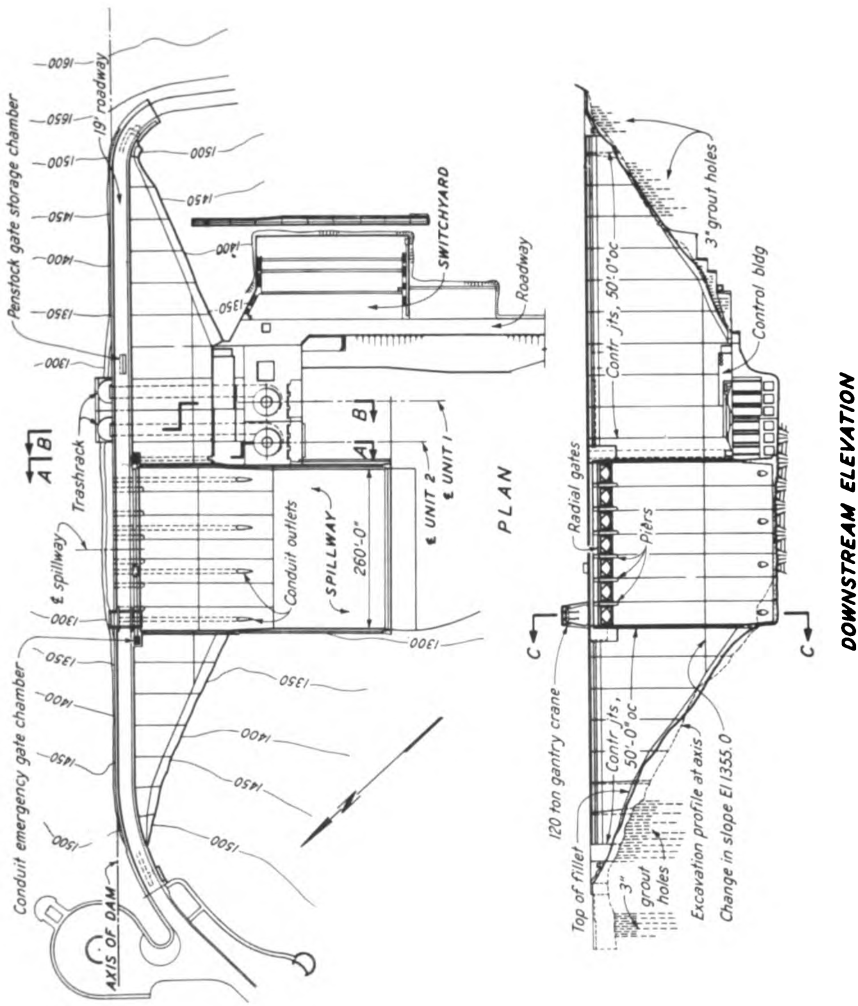
The spiral case is of plate-steel riveted construction and is riveted to the cast-steel stay ring. It is designed to withstand the maximum pressure imposed by a combination of maximum head plus water hammer pressure. Figure 50 shows the scroll case during erection. The runner is of cast-steel construction with 19 buckets. Water to the runner is controlled by 24 cast-steel wicket gates. The shaft is guided by an oil-lubricated guide bearing located above the head cover. An alternating-current motor-driven pump supplies oil to the bearing under normal conditions, and a direct-current motor-driven pump comes into operation automatically in case the alternating-current motor-driven pump fails to supply the bearing with sufficient oil.

Unit 2 at Hiwassee is a vertical pump-turbine manufactured by the Allis-Chalmers Manufacturing Co. It is direct-connected to a generator motor which is rated 80,500 kilovolt-amperes as a generator and 102,000 horsepower as a motor. As a turbine this unit is rated 83,000 horsepower at a net head of 190 feet and operates at a speed of 105.9 revolutions per minute clockwise. As a pump the rating is 3,900 cubic feet per second at a total dynamic head of 205 feet, and the unit operates at a speed of 105.9 revolutions per minute counterclockwise. Figure 51 shows a section of the pump turbine and generator motor.

The Hiwassee pump turbine unit is similar in appearance to a conventional Francis-type turbine. The embedded parts consist of a plate-steel draft tube liner, plate-steel discharge ring, cast-steel stay ring, plate-steel spiral case, and plate-steel pit liner. The spiral case is of welded construction and is welded to the stay ring. Shop welds were furnace annealed and the stay ring and spiral case were sectionalized to provide a minimum of field welding consistent with ease of handling and shipping. The field welds were stress relieved by the low temperature flame stress relieving process, and the completed stay ring and spiral case were hydrostatically tested at a pressure of one and one-half times the design pressure.

The flow of water to the impeller runner is controlled by 20 cast-steel wicket gates. The wicket gates are connected by suitable levers and links to the shifting ring, which is in turn connected to the two gate servomotors. The servomotors, acting under oil pressure from the governor, control the wicket gate opening.

The impeller runner (fig. 52) is probably the one piece which most distinguishes the pump turbine from a conventional Francis turbine. Figure 52 shows the runner in the erection area after the three sections were bolted together. The impeller runner for unit 2 has 6 vanes compared to 19 vanes for the conventional unit and has a considerably larger diameter at the center line of the distributor. The impeller runner is also set 6 feet lower with respect to tailwater than the conventional runner. The larger diameter and lower setting are dictated by the pumping requirements of the unit.



Penstock gate storage chamber
19' roadway
SWITCHYARD
Roadway
Trashrack
A B
℄ spillway
Conduit outlets
SPILLWAY
260'-0"
℄ UNIT 2
℄ UNIT 1
PLAN
Conduit emergency gate chamber
AXIS OF DAM
3" grout holes
Control bldg
Contr jts, 50'-0" oc
Radial gates
Piers
C
120 ton gantry crane
Contr jts, 50'-0" oc
Top of fillet
3" grout holes
Excavation profile at axis
Change in slope El 1355.0
DOWNSTREAM ELEVATION

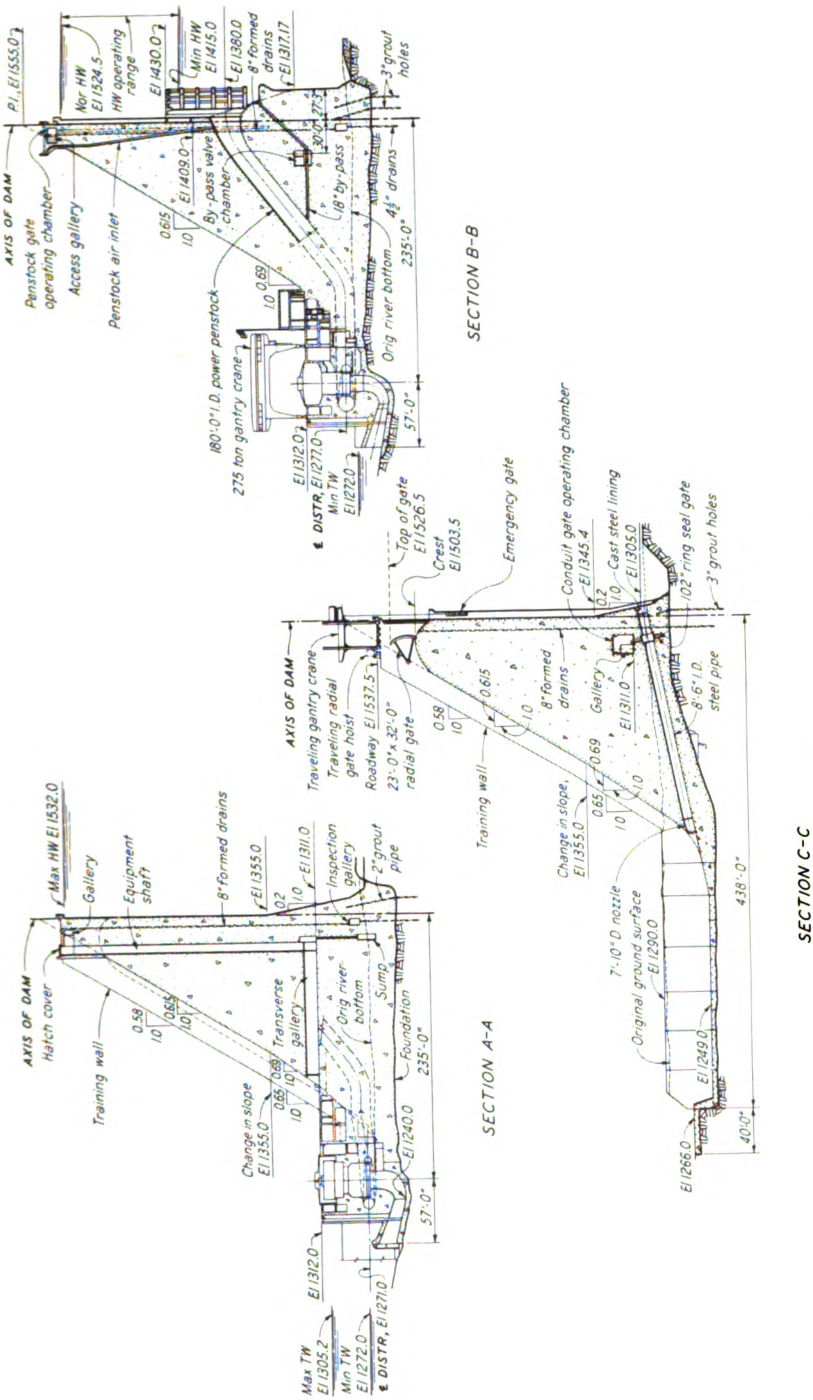


FIGURE 46.—*Hiwassee—plan, elevation, and sections.*

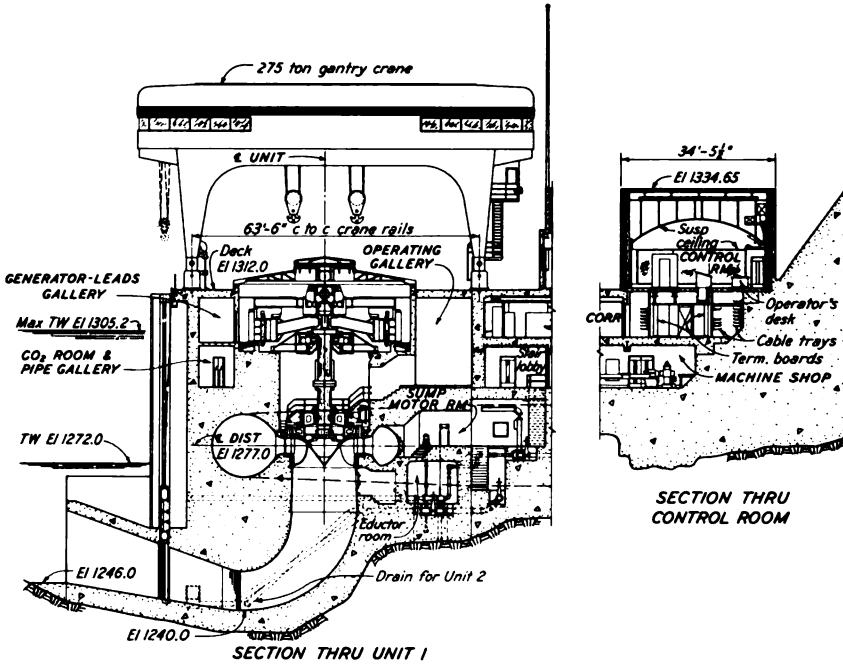


Figure 47.—*Hiwassee powerhouse cross section—unit 1.*

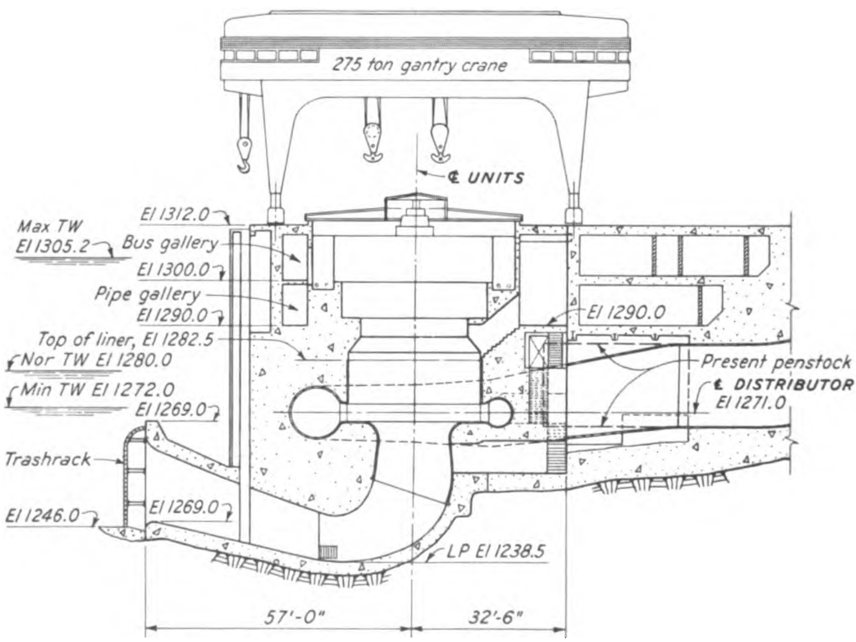


Figure 48.—*Hiwassee powerhouse cross section—unit 2 pump-turbine.*

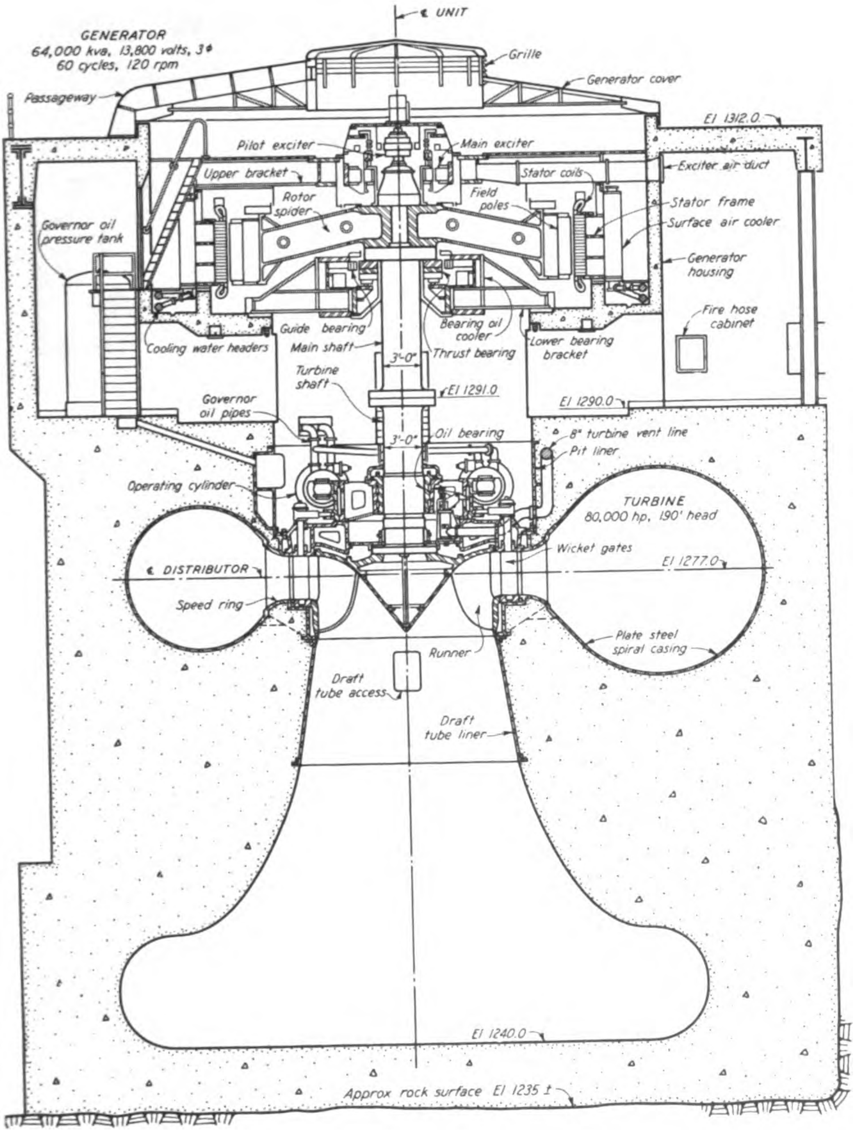


FIGURE 49.—*Hiwassee unit 1 turbine and generator section.*

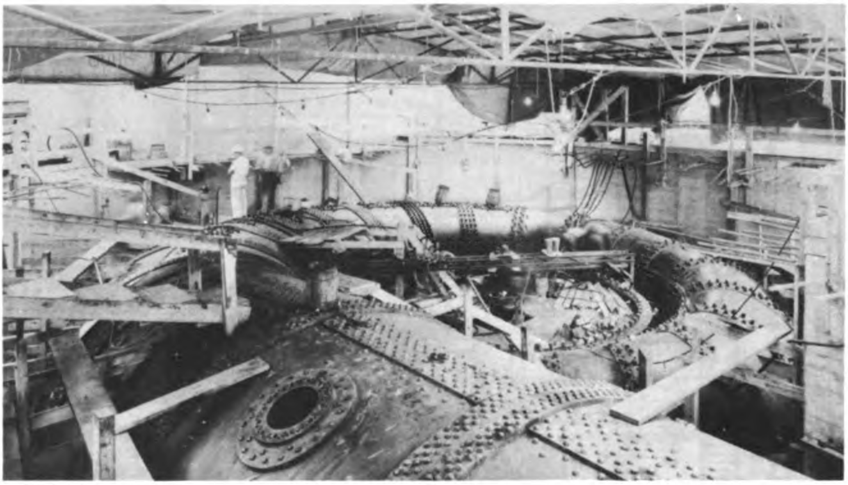


FIGURE 50.—*Hiwassee unit 1 riveted steel scroll case during erection.*

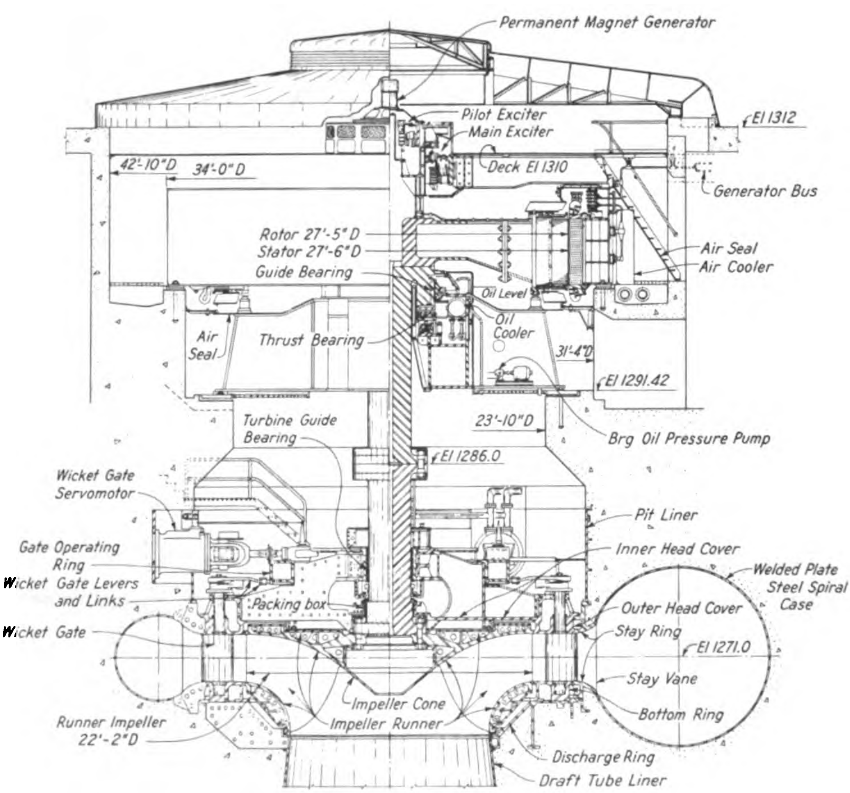


FIGURE 51.—*Hiwassee unit 2—pump-turbine and motor-generator section.*

FIGURE 52.—*Hiwassee unit 2 pump-turbine runner during assembly.*

Additional items for the pump turbine unit which are not ordinarily provided for a conventional turbine are:

1. Draft tube trashracks to prevent trash from entering the impeller runner during pumping operation (fig. 48). It is important that these trashracks do not become clogged and thus lower the effective tailwater level enough to cause cavitation in the impeller runner. In order to prevent operation of the unit as a pump under these conditions, TVA has provided an additional tailwater level indicator inside the trashracks. This indicator has electrical contacts for alarm and shutdown in case the effective tailwater level becomes too low.
2. Equalizing pipes connected between the head cover and the draft tube to decrease the pressure under the head cover. This reduction in pressure has the effect of reducing the hydraulic thrust and reducing the disk friction.
3. Special flowmeters which totalize the net flow through the plant. The flow through the pump turbine is added when the unit is generating and subtracted when it is pumping.
4. Wicket gate brakes to prevent chattering or vibration of the wicket gates during operation as a pump, which model tests and operating experience on similar units have indicated might occur at certain gate openings. The brakes are air operated and act directly on the gate stems. The brakes are automatically controlled, so that they are lightly applied whenever the gates are moving in either direction, and are fully applied whenever the gates are not moving.
5. The usual facilities for blowing the water down below the runner to reduce the power required for operation of the unit as a condenser. The blowdown facilities will also be used on this unit to reduce the torque required when starting as a pump and to gradually reduce the power input when shutting the unit down from pumping operation.

In accordance with the contract, efficiency and capacity tests were made on a homologous model in the turbine manufacturer's hydraulic laboratory. These tests indicated that capacity and effi-

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ciency guarantees would be exceeded and that the prototype would meet the TVA's requirements for a pumped storage unit. Field tests have been made on this unit and are described in chapter 3.

Governors

The governors for both units are of single cabinet-actuator type manufactured by the Woodward Governor Co. Each governor is complete with governor head, sump tank, pressure tank, two oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the units from the control room.

The two oil pumps for unit 1 are the herringbone-gear type each with a capacity of 200 gallons per minute at 300 pounds per square inch and driven by a 50-horsepower motor. The unit 1 sump tank, which is located in the base of the cabinet, has a volume of 150 cubic feet; and the pressure tank, which is located behind the cabinet, has a volume of 195 cubic feet.

Unit 2 has two oil pumps with a capacity of 300 gallons per minute each at 300 pounds per square inch and driven by 75-horsepower motors. The sump tank, located in the base of the cabinet, has a volume of 154 cubic feet; and the pressure tank, located behind the cabinet, has a volume of 261 cubic feet.

Generators

Unit 1 generator, manufactured by the Westinghouse Electric Corp., is an enclosed, water-cooled, vertical shaft type with a vertical cylindrical concrete wall or housing and removable weather cover (fig. 49). Its normal rating is 64,000 kilovolt-amperes or 57,000 kilowatts at 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and 120 revolutions per minute. The main and pilot exciters are mounted above the main rotor, and a combination Kingsbury-type thrust bearing and segmental guide bearing is located below the generator rotor in an oil reservoir of 800-gallon capacity.

Unit 2 generator-motor, manufactured by the Allis-Chalmers Manufacturing Co., is an enclosed, water-cooled, vertical shaft type with a housing of a vertical cylindrical concrete wall and a removable weather cover (fig. 51). Its normal rating as a generator is 70,000 kilovolt-amperes or 59,500 kilovolts at 0.85 power factor lag, 13,800 volts, 3 phase, 60 cycles, and 105.9 revolutions per minute; its normal rating as a motor is 102,000 horsepower at 0.95 power factor lead, 13,500 volts, and 105.9 revolutions per minute. The main and pilot exciters are mounted above the main rotor, and a combination Kingsbury-type thrust bearing and segmental guide bearing is located below the rotor in a 3350-gallon-capacity oil reservoir. The thrust bearing is arranged to operate in either direction of rotation. It is also equipped with a high-pressure oil pump which provides an oil film on the bearing surface during the time that the unit is being started or stopped.

Oil systems

Both lubricating and insulating oil pumping and purification equipment are in the oil purification room in the service bay. The oil storage tanks for both systems are outside the powerhouse below the switchyard along the left bank of the tailrace.

The governor and lubricating oil system consists of one 30-gallon-per-minute oil transfer pump for handling both clean and dirty oil, one 300-gallon-per-hour purifier, and 1 clean- and 1 dirty-oil storage tank, each of 4,700-gallon capacity, and a complete piping system.

The transformer and circuit breaker oil system consists of one 100-gallon-per-minute clean insulating oil pump, one 600-gallon-per-hour insulating oil purifier, three insulating oil storage tanks for the dirty transformer oil, dirty circuit breaker oil, and clean insulating oil, each with a 9,000-gallon capacity, and a complete piping system for filling and draining the electrical equipment through hose connections in conveniently located valve boxes. The equipment is arranged for gravity flow of dirty oil in draining the equipment to the dirty-oil storage tanks.

Compressed air systems

The compressed air system for station service and generator brakes is supplied from a stationary compressor in the compressor and unit board room of the electrical bay, delivering 105 cubic feet per minute at 100 pounds per square inch. Also provided are a portable, electric-motor-driven compressor of equal capacity; a complete piping system with service outlets in the powerhouse, deck, and switchyard, and an aftercooler, pressure governor, and 100-cubic-foot receiver near the stationary air compressor.

A draft tube evacuation compressed air system depresses the water level in the draft tube of both units. The system includes two stationary compressors located in the compressor and unit board room in the electrical bay. One compressor, rated at 284 cubic feet per minute and 100 pounds per square inch, is intended for standby service. The second air compressor, which is a water-cooled, 2-stage, double-acting, vertical Y cross-head type with a water-cooled intercooler, will normally supply the system at a capacity of 546 cubic feet per minute and 100 pounds per square inch. A pressure governor, water-cooled aftercooler, and four air receivers with a total capacity of 1,450 cubic feet are included in the system. A complete piping system with diaphragm-actuated control valves (float-switch-controlled) for each unit is installed for automatic release of air to maintain the depressed water level.

A motor-operated gate valve in the unit 1 turbo vent line is closed automatically prior to operation of the unit 1 evacuation system, and similarly a motor-operated globe valve in the unit 2 vent line is closed automatically prior to operation of its evacuation system.

The 300-pound-per-square-inch governor air compressor, with a capacity of 8 cubic feet per minute, supplies the governor pressure tanks of both units and the wicket gate air brake system at unit 2. The wicket gate air brake system includes a 15-cubic-foot receiver, air filter, and one brake cylinder in the pump-turbine pit for each pair of wicket gates, with a complete piping system for automatic remote control of the brakes. By means of an arrangement of pressure reducing valves, solenoid-operated valves, and a special 3-port check valve, the system is operated to apply reduced pressure during movement of the wicket gates and to fully apply the braking pressure when the wicket gates reach a fixed position during pumping operation of the unit.

Raw water system

The raw water system provides water for unit cooling and lubrication, station services, fire protection, and other miscellaneous uses. Raw water for use in the powerhouse and switchyard is normally supplied from the unit 1 penstock bypass with intake at elevation 1353 on the forebay wall. Failure of a portion of the embedded piping for the original intake at elevation 1309.29 necessitated such an alternate arrangement. Water flows by gravity through a strainer, then branches into three systems. The first system supplies water to the air compressors, aftercoolers, air-conditioning equipment, and station service outlets, and for fire protection in the powerhouse and switchyard. The second system supplies water for operation of the eductors. The third system passes through a pressure regulating valve, which has an outlet pressure of approximately 36 pounds per square inch, and then branches to supply cooling and lubricating water to each unit. The branch to unit 1 supplies the generator air and oil coolers, and the turbine packing box and upper runner seal. The branch to unit 2 supplies the motor-generator air and oil coolers, and the pump-turbine bearing oil cooler, runner seals, and packing box.

Two raw water pumps, located in the valve chamber of the inspection gallery in the dam, draw water from multiple intakes in the forebay through a strainer, and thence to the mixing tank in the filter plant. These pumps, each of which has a capacity of 50 gallons per minute against a total head of 450 feet, also furnish seal water to the sluice conduit ring seal gates and for filling the conduits between the ring seal gates and emergency gates to facilitate raising the latter.

A motor-operated valve serves as a complete shutoff for all water to each unit. The valve is opened or closed by manual remote control from the control room when the unit is started or stopped. Flow through the generator air coolers is controlled automatically by a motor-operated, thermostatically controlled, proportioning valve actuated by a feeler bulb in the generator air housing.

The raw water system for the turbine, pump turbine, generator, and motor generator has its own series of alarm circuits, operated by flowmeters, to indicate low flows. Also, flowmeters in the following supply lines have an additional electric contact to shut down or prevent starting the unit on low flow: (a) supply to the turbine runner seal at unit 1, (b) supply to the pump turbine runner seals, oil cooler, and packing box at unit 2, (c) supply to the generator bearing oil cooling coil at unit 1, and (d) supply to the motor-generator bearing oil coolers at unit 2.

Treated water system

All treated water for the station was originally supplied from the Hiwassee village filter plant and a 50,000-gallon storage tank located on the left bank of the river above the dam. A 3-inch main runs the entire length of the dam through the inspection gallery with 2-inch outlets at the overlook building and powerhouse. The treated water system is reduced in pressure to 60 pounds per square inch at the entrance to the powerhouse and serves the plumbing and sanitary fixtures and 1-inch hose service outlets.

In 1957 the village treatment plant had about served its useful life and, because of the virtual abandonment of the village, a new and smaller system was designed. This consists of an extremely soft water supply with an excellent bacteriological history from a spring at the intersection of the Turtletown Highway and the powerhouse access road. A treatment plant is adjacent to this intersection and consists of marble beds to stabilize the corrosive raw water, slow sand filters having a combined capacity of 10 gallons per minute, a filtered water clearwell, 2 hypochlorinators, and 2 electric-motor-driven service pumps. The latter are automatically controlled as pressure increases or decreases in the system. On the hillside above the dam on the left bank a new concrete storage tank of 5,500-gallon capacity receives the water from the treatment plant. This tank is connected to the existing powerhouse treated water system supplying it and the visitors' facilities on the right bank with water by gravity.

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse discharges into a 2,150-gallon septic tank located in mass concrete below the elevation 1290 floor in the service bay. Under normal conditions of tailwater, the effluent from the tank drains directly to tailwater through a 4-inch pipe in the downstream wall of the service bay, terminating at elevation 1266. When tailwater rises above elevation 1285, the effluent is diverted to a sewage sump located in mass concrete adjacent to the septic tank. An automatic float control starts a 225-gallon-per-minute sewage pump when water rises in the sump to elevation 1286.5, and the waste is discharged to tailwater through a 4-inch pipe, terminating at elevation 1266. The sewage pump stops when water falls to elevation 1284.

Drainage and unwatering

In general, all drainage except roof drainage is discharged into the station drainage sump located upstream from unit 1. This sump is serviced by a 6-inch eductor and a 300-gallon-per-minute vertical sump pump. The sump pump acts as a standby should the eductor fail to handle the drainage. When unit 2 was installed it was necessary to add a sump in the unit 2 draft tube access to take care of its drainage, due to the lower floor elevation. Thus sump is serviced by two 70-gallon-per-minute vertical sump pumps.

All drainage to galleries in the dam reaches a sump below the lower gallery floor by means of open gutters or embedded pipes. A 12-inch pipe drains the sump by gravity to tailwater. A vertical, deepwell-type, 500-gallon-per-minute sump pump discharges into the 12-inch pipe, and was provided to be used only if necessary during periods of high tailwater.

A 12-inch eductor unwaters the draft tube and scroll case of both units. At the time of the unit 2 installation, operating experience on unit 1 had proven that the 12-inch eductor would be inadequate for unwatering the draft tube because of leakage through the draft tube and wicket gates. As a result of this experience, a 5,000-gallon-per-minute, deepwell, turbine-type pump was installed in a pump well in the unit 2 area with its motor mounted on the floor of the pipe gallery. Units 1 and 2 have draft tube drain outlets con-

nected to both the 12-inch eductor and the pump well. Normally, the 5,000-gallon-per-minute pump will be used for unwatering operations. The 12-inch eductor can be used to augment the pump capacity, if needed, and must be used to unwater either unit scroll case.

Fire protection

An automatic CO_2 fire-extinguishing system protects the generators and the oil purification room. The system consists of an initial discharge bank and a reserve bank each containing 18 cylinders, 2 delayed discharge banks of 8 cylinders each, piping, nozzles, and auxiliary equipment. The initial bank is arranged for simultaneous discharge of 18 cylinders to either generator or 10 cylinders to the oil purification room. The reserve bank is arranged to function in the same manner.

Portable CO_2 fire-extinguishing units are conveniently located in the powerhouse and switchyard. Three 100-pound buggy-type units are provided for the various levels in the switchyard.

Raw water from the reservoir is supplied for general fire protection in the powerhouse and switchyard. There are conveniently located fire hose racks in the powerhouse and three 4-inch fire hydrants with a fire hose cart in the switchyard.

Service equipment

The machine shop, which is conventional size and located in a separate room in the electrical bay adjacent to the turbine room, contains the equipment listed in table 14, page 626.

A 5-ton service hoist, completely enclosed and mounted on a geared trolley, is located in the service bay for handling parts of motors, transformers, and equipment. The hoist is the monorail type, electrically operated, and is mounted on a I-beam bridge which travels on a track supported on steel beams in the rotor hatch area. Bridge travel is by means of hand chain hoist.

An electrically operated, 1,500-pound, 20-foot-per-minute freight elevator with push button control is located at the south end of the electrical bay. The elevator is used to handle miscellaneous freight between the turbine floor and the powerhouse deck, with an intermediate landing at elevation 1301.3.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, lobby, and offices. The remainder of the powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

For flexibility of control, the air-conditioning spaces are served by two combination heating, cooling, and ventilating systems each

with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by circulating lake water through the cooling coils.

A summary of the ventilating and heating requirements is as follows:

Cubic feet per minute of air supplied and exhausted	103,550
Kilowatts of installed electric heating	427

WATTS BAR

Watts Bar Dam (fig. 53) is on the Tennessee River at river mile 529.9, between Chattanooga and Knoxville, Tenn. The project provides storage capacity for flood control and extends the navigable channel from the head of the Chickamauga pool to Fort Loudoun Dam near Lenoir City, Tenn., a distance of 72.4 miles. Authorization, construction, operation, and cost data are as follows:

Authorization	May 3, 1939
Construction started	July 1, 1939
Closure	January 1, 1942
Commercial operation:	
Unit 3	February 11, 1942
Unit 2	April 6, 1942
Unit 1	July 23, 1942
Unit 5	March 12, 1944
Unit 4	April 24, 1944
Cost of the 5-unit project, including switchyard	$35,577,684

The project, of which the plan, elevation, and sections are shown in figure 54, consists of an earth embankment on the left flood plain, navigation lock, spillway dam across the main river channel, powerhouse, and control building and switchyard on top of the west abutment. A view of the powerhouse and control building is shown in figure 55. The highway bridge over the dam, designed by TVA for the State of Tennessee and the U.S. Bureau of Public Roads, was started in 1955 and officially completed early in 1957.

The navigation lock is a single lift structure with a chamber 60 by 360 feet and a maximum lift of 70 feet. The spillway dam includes a nonoverflow section, a spillway section, and a trashway. The spillway section is a gravity structure with an ogee-type overfall and has twenty radial gates, 40 feet wide by 32 feet high, designed for the passage of a maximum flood of 560,000 cubic feet per second. One floating steel caisson bulkhead is provided for emergency closure of a spillway opening. The gates are operated from the spillway deck by two traveling hoists. The trashway section, adjacent to the powerhouse, is equipped with a 12-foot-high double leaf trash gate which is operated by the intake gantry crane.

The powerhouse intake is located between the spillway dam and the service bay at the right bank. The intake provides water passages for five hydraulic turbines spaced 73 feet on centers. Two sets of three vertical lift, fixed wheel intake gates, and one set of emergency steel stoplogs are provided and are handled by a 50-ton-capacity gantry crane.

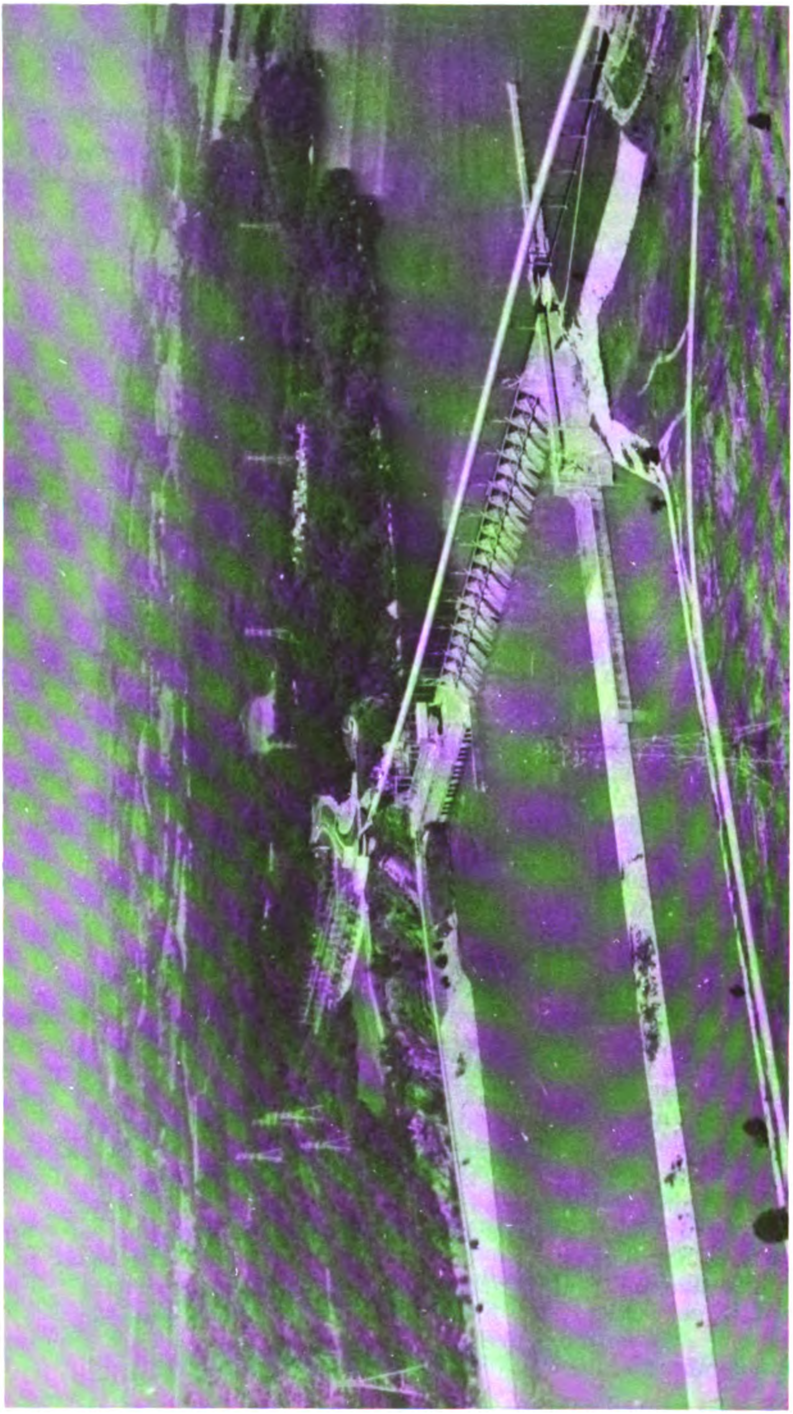


FIGURE 53.—*Watts Bar project.*

The powerhouse, of which a cross section is shown in figure 56, contains five units, all of which were installed in a continuous construction program. The powerhouse is the semioutdoor type with enclosed generator room and outdoor gantry crane. Major pieces of equipment are handled by a 225-ton-capacity gentry crane through hatches in the roof. One set of three vertical lift sliding steel gates is provided for closure of the draft tubes.

The service bay forms a continuation of the powerhouse and intake to the right abutment. A screen house, which serves as the water intake for the downstream steam plant, adjoins the upstream face of the service bay at the base of the bluff.

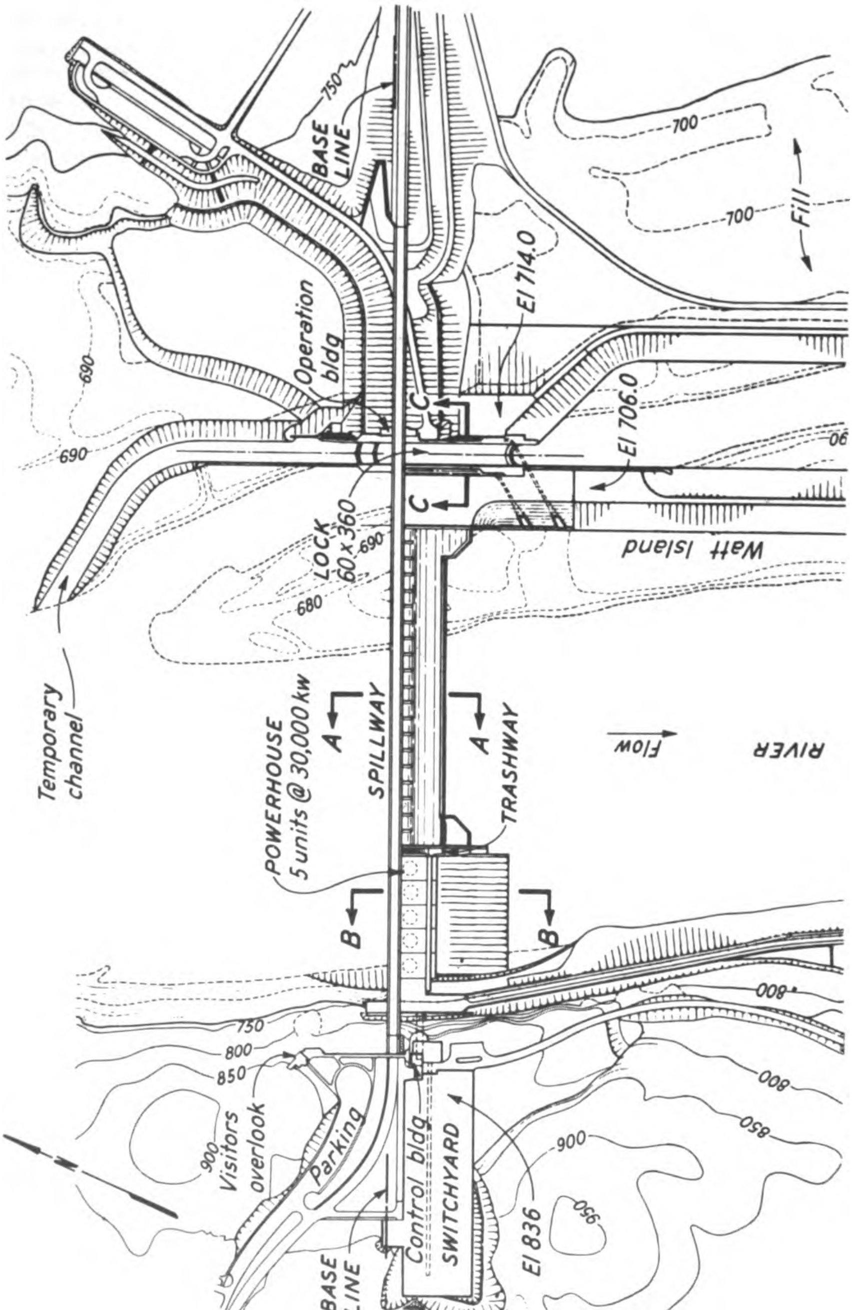
The control building on the bluff is connected with the powerhouse by a vertical shaft and a horizontal tunnel at the service bay level. Both a public-use elevator and a service elevator are installed in the shaft. The switchyard, with insulating oil purification and storage facilities, is located on a graded area on the bluff near the control building.

Turbines

Five Kaplan-type hydraulic turbines manufactured by the Baldwin-Lima-Hamilton Corp. are direct-connected to the 33,333-kilovolt-ampere synchronous generators (fig. 57). The turbines are rated 42,000 horsepower at a net head of 52 feet and operate at a speed of 94.7 revolutions per minute. They are designed to operate under any head from a minimum of 40 feet to a maximum of 60 feet and to withstand a maximum runaway speed of 243 revolutions per minute. At rated conditions the value of specific speed is 139 and the centerline of the runner is approximately 14 feet below normal tailwater elevation giving a plant sigma of 0.89.

The Watts Bar units have concrete spiral cases with cast-steel stay rings. The stay rings are designed to support the weight of superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners each have five cast-steel blades set in a cast-steel hub which contains the blade operating mechanism. Certain areas on the back side of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder, located at the top of the turbine shaft and operated by governor oil pressure, controls the blade tilt. The shaft is guided by a water-lubricated guide bearing a molded plastic material or Insurok located in the bore of the header cover barrel.

The draft tube and spiral case outlines are normally designed by the turbine manufacturer to suit his particular turbine. During the summer of 1939 preparations were being made for construction in the field, but money was not yet available for the purchase of the generating equipment. To be able to proceed with the general design and initial construction of the powerhouse, a compromise draft tube and spiral case design was developed with the cooperation of the four major waterwheel manufacturers. In order that each manufacturer could satisfy himself that this design was suitable for his particular turbine, a contract was placed with three of the manufacturers to cover the cost of a model and model tests made with their turbine in this setting. The fourth manufacturer advised that


BASE LINE
750
700
Fill
El 714.0
Operation bldg
690
C
El 706.0
LOCK 60 x 360
Watt Island
680
Temporary channel
POWERHOUSE 5 units @ 30,000 kw
A
SPILLWAY
TRASHWAY
Flow
RIVER
B
800
850
900
Visitors overlook
Parking
Control bldg
SWITCHYARD
El 836
950
BASE LINE

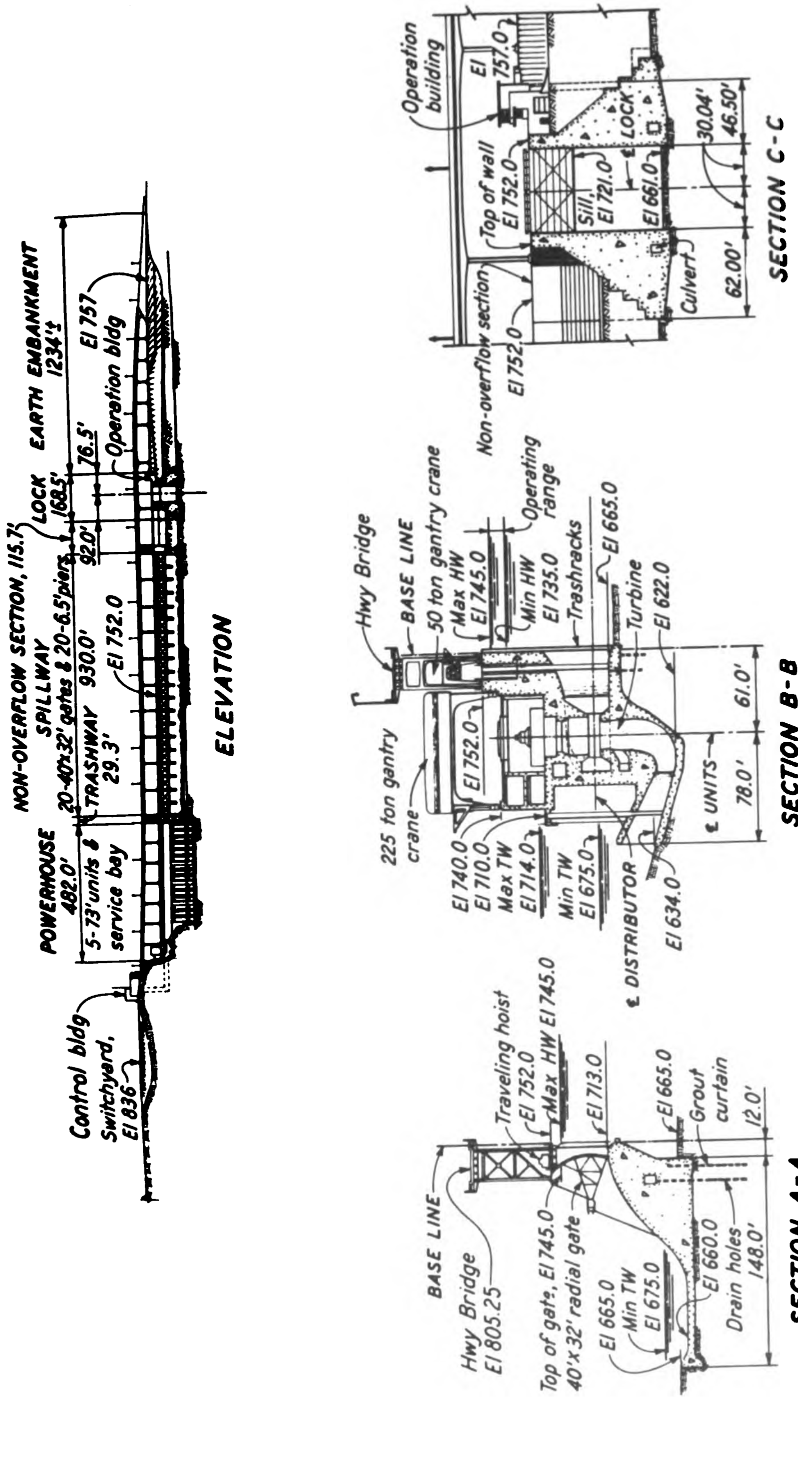


FIGURE 54.—Watts Bar—plan, elevation, and sections.

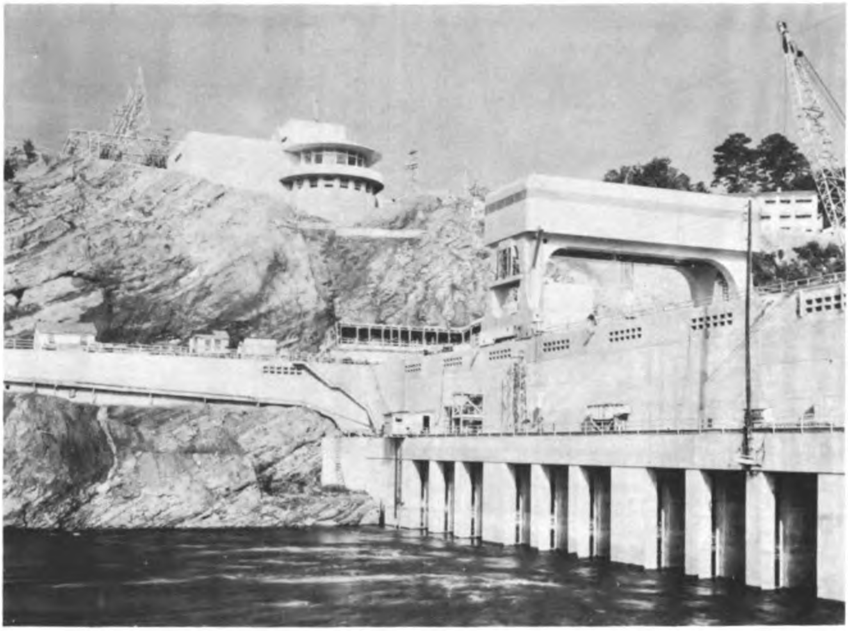


FIGURE 55.—*Watts Bar powerhouse and control building.*

the design was so close to the one that he would recommend that no tests were necessary. Following the tests, the other three manufacturers advised that their turbines would operate satisfactorily with the spiral case and draft tube design adopted by TVA.

Efficiency acceptance tests were made at the manufacturer's hydraulic laboratory on a homologous model. These tests indicated that the prototype would exceed the efficiency guarantees by an average of about 4 percent and would meet or exceed the capacity guarantees at all heads.

Governors

The governors are the cabinet actuator type manufactured by the Woodward Governor Co. A twin actuator cabinet is provided for units 1 and 2 and units 4 and 5, and a single-type cabinet for unit 3. The single and one twin actuator cabinet can be seen in figure 58. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for control of the turbine from the actuator. The twin governors have interconnected oil pressure systems so that both governors may be operated from one oil pump; the single governor is provided with two oil pumps one of which operates as a spare. Each oil pump has a capacity of 250 gallons per minute at 300 pounds per square inch and is driven by a 60-horsepower motor. Each pressure tank has a volume of 313 cubic feet. The sump tanks for the twin governors have a volume of 350 cubic feet, and the single governor sump tank a volume of 260 cubic feet. Index tests conducted on unit 1 are included in appendix A.

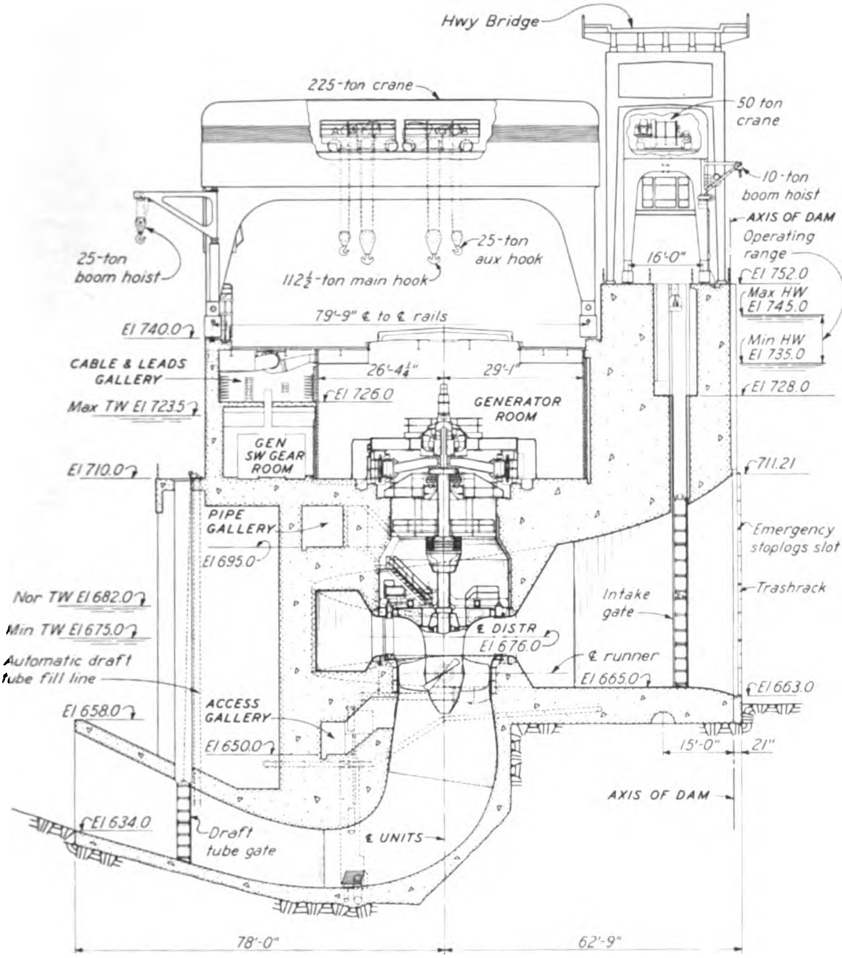


Figure 56.—*Watts Bar powerhouse cross section.*

Generators

The five generators, manufactured by the Westinghouse Electric Corp., have a normal rating of 33,333 kilovolt-amperes or 30,000 kilowatts at 0.9 power factor, 60 cycles, 3 phase, 13,800 volts, and 94.7 revolutions per minute. The main and pilot exciters are mounted above the main rotor. An enclosed, water-cooled air-circulating system and CO_2 fire protection are provided. A combination Kingsbury-type thrust bearing and segmental guide bearing, located below the generator rotor, is immersed in an oil reservoir with a capacity of 1,550 gallons of oil. Cooling coils in the generator bearing oil reservoir are designed to pass a maximum of 35 gallons per minute of cooling water.

Each generator is equipped with eight double cylinder units of combined air-operated brakes and oil-operated jacks mounted on the bearing bracket arms, designed for 100-pound-per-square-inch air pressure and 2,000-pounds-per-square-inch oil pressure.

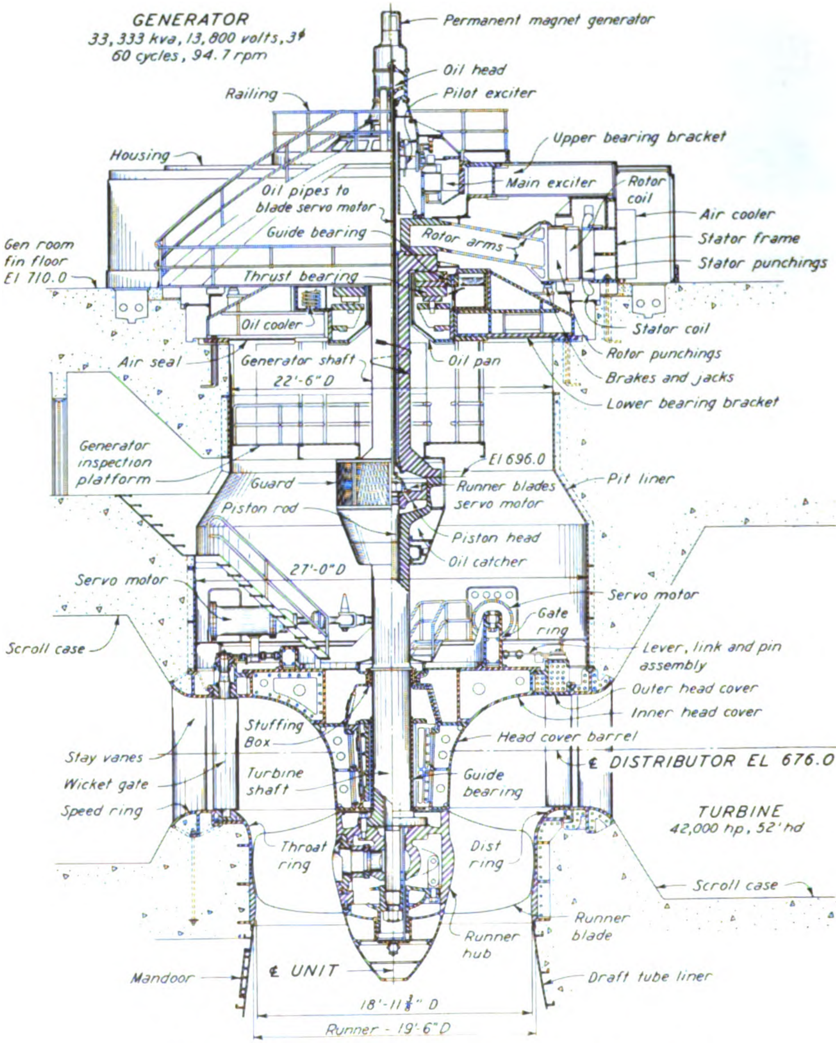


Figure 57.—*Watts Bar—turbine and generator section.*

The generators, a section of one of which is shown in figure 57, are the indoor type. A view of the generator room is shown in figure 58.

Oil systems

The governor and lubricating oil purification system consists of one 375-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 3,800-gallon capacity; and the necessary connecting piping for the supply and return of oil to the appropriate mechanical equipment. The purifier, pumps, and storage tanks are located in the service bay.

FIGURE 58.—*Watts Bar generator room.*

The insulating oil system, all of which is located in or adjacent to the switchyard, consists of the oil purification building housing the pumps and purification equipment, storage tanks in the yard adjacent to the building, and connecting piping. One clean- and one dirty-oil pump, each of 100-gallon-per-minute capacity, an insulating oil purifier with a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press, two 7,000-gallon-capacity dirty transformer oil tanks, one 7,000-gallon-capacity dirty circuit breaker oil tank, and one 7,000-gallon-capacity clean insulating oil tank make up the major equipment of the system. Valve boxes are conveniently located for filling and draining the electrical equipment through hose connections.

A fixed piping system for filling and emptying the runner hub is also provided in the powerhouse.

Compressed air systems

A complete piping system, with service outlets, distributes compressed air throughout the powerhouse to the generator brakes and to the intake and draft tube decks. A 2-inch header supplies compressed air to the screen house for bubbler service. A stationary, single-stage, double acting, motor-driven air compressor is located in the basement of the service bay. The compressor capacity is 105 cubic feet per minute at 100-pound-per-square-inch pressure. The system includes a water-cooled aftercooler, a 150-cubic-foot-air receiver, and control equipment for automatic operation. A cross connection permits the draft tube evacuation system to supply the station service air system.

A portable air-cooled motor-driven air compressor of 105-cubic-foot-per-minute capacity at 100-pound-per-square-inch pressure is also available for general service.

The draft tube evacuation air compressor is a stationary, single-stage, double acting, motor-driven unit with a capacity of 300 cubic feet per minute at 100-pound-per-square-inch pressure. The system includes a water-cooled aftercooler, compressor control equipment for automatic operation, and four air receivers with a total volume of 2,000 cubic feet. A complete piping system is provided for depressing the water level in the draft tubes with manual remote con-

trol from the actuator cabinet. Receivers and compressor are located in the basement of the service bay.

Compressed air for the governor system is supplied by an 8-cubic-foot-per-minute compressor at 300-pound-per-square-inch pressure. An independent piping system connects the compressor with the governor pressure tank of each unit.

Raw water system

An intake in the scroll case provides circulating cooling water to each generating unit. The water passes through a twin strainer and is pumped through the generator air and oil coolers by the 1,200-gallon-per-minute unit cooling water pumps. The generator cooling water is returned to the scroll case. A 1,200-gallon-per-minute emergency cooling water pump is located in the service bay as a standby unit with an intake in the forebay. The piping system is arranged so that generator cooling water may be supplied from a discharge header from this pump or from an adjacent unit.

Turbine raw water requirements are normally supplied by gravity from the scroll case water intake, passing through a separate twin strainer to the turbine bearing and wheel pit unwatering sump educator. A cross connection gives an emergency supply of turbine raw water from the unit cooling water pump discharge.

The forebay raw water intake provides gravity flow of strained cooling water to the gas-electric generator set, which is equipped with a 50-gallon-per-minute gear-driven pump, the air compressors, and aftercoolers in the service bay, with an emergency connection for raw water supply to the filter plant. This intake also supplies the 150-gallon-per-minute air-conditioning cooling water pump which provides water to the air-conditioning plant condenser in the control building.

Alarm circuits operated by flowmeters to indicate low flow are in the supply lines to the generator air and oil coolers, turbine bearing, and gas-electric generator set. The flowmeters in the turbine bearing water supply lines have an additional electrical contact to shut down or prevent starting the unit on low flow.

Treated water system

The filter plant provides treated water for fire protection and sanitary fixtures in the powerhouse, control building, lock, and switchyard, with a 4-inch supply header to the Watts Bar Steam Plant. The filter plant is a conventional type consisting of two 50-gallon-per-minute rapid sand gravity filters, a mixing chamber, a coagulation basin, lime and alum chemical feeders, two chlorinators, a 13,185-gallon clearwell, one 450-gallon-per-minute backwash pump, two 250-gallon-per-minute service pumps, and two elevated storage tanks with a total capacity of 100,000 gallons. For a complete description of this treatment plant refer to chapter 9, "Treated Water Systems."

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse discharges into a 500-gallon steel septic tank located at elevation

695 in the service bay. Under normal conditions of tailwater, the effluent from the tank drains directly into the tailrace by gravity through an outlet at elevation 673 in unit 1 draft tube pier. When tailwater rises above elevation 695, the effluent from the tank is diverted to the station sump from which it will be automatically discharged to tailwater by the drainage pumps. The waste from the toilet fixtures, located on the generator room floor at unit 3, drains directly into the unit 3 draft tube pier. During high tailwater a valve in the waste line is closed to prevent water backing up into the fixtures, the use of the facilities being discontinued.

The sanitary waste from the toilet facilities in the control building discharges into a 1,750-gallon metal septic tank located in the basement of the building. The effluent from the tank discharges into an 8-inch storm sewer which terminates in a ditch which flows into the river downstream from the dam.

The sanitary waste from the toilet facilities in the lock operation building discharges into a 1,200-gallon metal septic tank located in the basement of the building. The effluent from the tank discharges through a 6-inch cast-iron pipe, terminating on the downstream end of the lock.

Drainage and unwatering

In general, all powerhouse drainage, except that from roof and deck, is discharged into the station sump which is in the basement of the service bay. It has a capacity of approximately 28,350 gallons and is serviced by two 300-gallon-per-minute, turbine-type pumps discharging directly to tailwater and operating automatically by float controls.

Drainage from the spillway gallery is normally discharged to the station sump through a 12-inch drain line. If an excessive amount of leakage accumulates in the gallery during periods of high water, it may be necessary to allow the gallery to fill up to tailwater level by closing the valve in the 12-inch line to the sump. Normally, open valves located in wells in spillway piers allow this excess leakage to equalize to tailwater; in this way they prevent any buildup of pressure or uplift on the spillway structure greater than that produced by tailwater. This equalizing system also prevents any possibility of flooding portions of the powerhouse, which would otherwise occur if the capacity of the pumps were exceeded.

The turbine pit at each unit is unwatered by a 1-inch jet eductor discharging into the drainage system to the station sump.

The elevator pits under the control building are drained by a small float-operated sump pump. The drainage is discharged into the powerhouse drainage system.

Each draft tube is provided with a screened outlet 2 feet above the low point. A 16-inch pipe, with a control valve, connects the screened outlet to an 18-inch header which discharges through its own control valve into the station sump. Unwatering valves are operated from the unwatering gallery. Two 5,000-gallon-per-minute, deepwell, turbine-type pumps are located in the station drainage and unwatering sump for draft tube unwatering. Either pump may be used on the station drainage system.

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Fire protection

There are three separate automatic CO_2 fire-extinguishing systems. All three systems are arranged for remote automatic electrical operation and for local manual operation.

One system, for protection of the generators, consists of an initial and a reserve bank of sixteen 50-pound cylinders each, and a delayed discharge bank of 10 cylinders. The initial bank is arranged for the simultaneous discharge of 16 cylinders to any generator. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent cylinder release to maintain a sufficient concentration of CO_2. Each generator has an air volume of approximately 10,500 cubic feet.

The second system, for protection of the oil storage, the oil purification, and gas-electric generator rooms, consists of one bank of ten 50-pound cylinders. Five cylinders can be discharged simultaneously into either the oil storage or oil purification rooms, or all 10 cylinders can be discharged into the gas-electric generator room.

The third system consists of 1 bank of 5 cylinders, all of which can be discharged into the oil purification building located in the switchyard.

Portable CO_2 fire-extinguishing hand units are conveniently located in the powerhouse and in the switchyard. Two 100-pound wheel-type units are also provided for the switchyard.

A supply of treated water, with fire hydrants and hose connections at convenient locations, is used for general fire protection in the powerhouse and switchyard.

Service equipment

Since the Watts Bar hydro and steam plants are close to each other, all major equipment repair is handled at the completely equipped machine shop of the Watts Bar Steam Plant. Therefore, a minimum of machine shop equipment, as listed in table 14, page 626, is installed at the hydro plant for minor operations in the assembly bay and machine shop.

Three automatic elevators, for which design data are included in table 6, page 394, are provided for the powerhouse and control building. These elevators have selective collective control and are push button type.

The passenger elevator in the control building has a total lift of 114 feet with landings at elevations 728, 818, 831, and 842 with the bottom landing in the powerhouse access tunnel. Its rated live load capacity is 5,000 pounds at a rated speed of 350 feet per minute. An employees' elevator, also in the control building in an adjacent shaft and which has the same lift and landings as above, has a rated live load capacity of 2,000 pounds at a rated speed of 350 feet per minute.

Another employees' elevator, located in the service bay, has a total lift of 42 feet with landings at elevations 710, 726, 740, and 752. Its rated live load capacity is 2,000 pounds at a rated speed of 200 feet per minute.

The emergency auxiliary power generating unit which is installed in the service bay has a 300-kilovolt-ampere, 0.8 power factor, 3-

phase, 60-cycle, 480-volt generator with direct-connected exciter, driven by a 425-brake-horsepower, 6-cylinder, 1200-revolution-per-minute gasoline engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, reception room, and offices. The remainder of the control building and the powerhouse are mechanically ventilated. Electric unit heaters supplemented by portable electric units located throughout the control building and powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur.

The air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system.

A summary of system design capacities is as follows:

Cubic feet per minute of air supplied and exhausted	342,200
Kilowatts of installed electric heating	716
Horsepower of refrigeration	50

WILSON

Wilson Dam is located at the foot of Muscle Shoals on the Tennessee River at river mile 259.4 and 2.5 miles east of Florence, Ala. It is situated 52.7 miles upstream from Pickwick Landing Dam and 15.5 miles downstream from Wheeler Dam.

The initial project, including the first 8 main generating units and 1 auxiliary unit, was constructed by the U.S. Corps of Engineers as a national defense measure. Begun in 1918 primarily as a source of power for the production of munitions during World War I, the Wilson hydro project provides, in addition to power generation, a navigable channel with the aid of Navigation Lock and Dam No. 1 from the headwater of Pickwick Reservoir to Wheeler Dam, and a small amount of storage capacity. Navigation Lock and Dam No. 1, with a maximum lift of 10 feet, is connected by the 2.6-mile Florence Canal to the lower chamber of a 2-lift lock at the dam. This double lock has a total lift of 90 feet.

In June 1956 work started at Wilson Dam on a new lock with a single lift of 100 feet and a 110- by 600-foot chamber nearly twice the size of the present lock chambers. By deepening the lower chamber of the present lock 10 feet and deepening Florence Canal by the same amount, together with improvement in the canal alignment, the need for Lock and Dam No. 1 will be obviated and it will be removed. The new lock is scheduled to be in operation in November 1959 and the estimated cost of the project is $38 million.

The Wilson project was acquired by TVA May 18, 1933, with a total rated capacity of 184,000 kilowatts. The intakes, powerhouse (including the first 8 units), switch building, switchyards, and control room were completed, ready to receive equipment for 10 additional units which were later installed by TVA. This completed the filling of the 18 stalls provided by the original design.

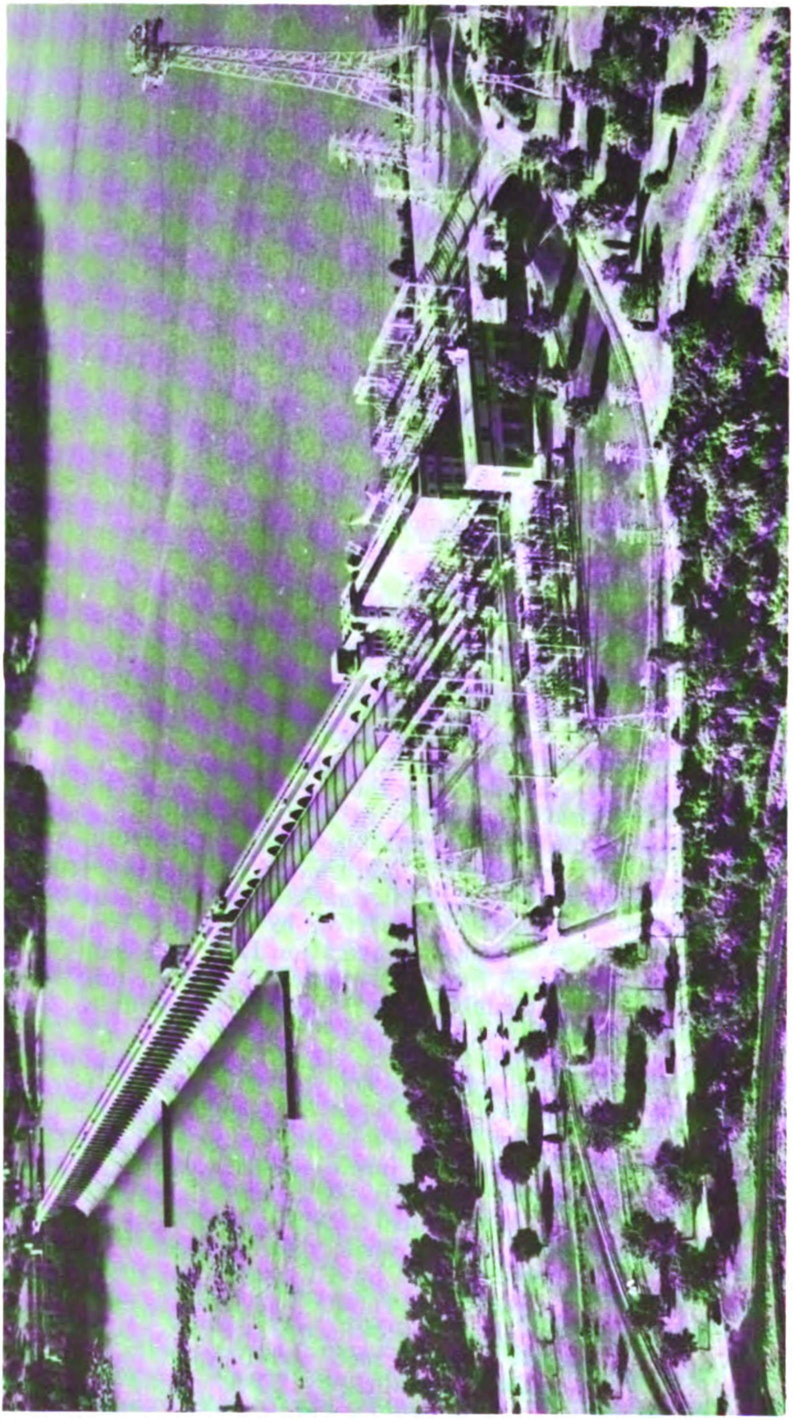

FIGURE 59.—*Wilson project.*

So great had the need for additional peak load capacity become by 1958, however, that it was economical to install additional capacity in this dam. The installation of three additional units of 54,000-kilowatt capacity each, more than double the size of the first 18 units, was authorized in 1958 and space to install them was obtained by elimination of the trash chute section and part of the bulkhead section of the dam. For the first time, TVA accepted bids from foreign manufacturers on such units. Whereas, the turbines were purchased from an American firm, a contract for the three generators was awarded to the Brown-Boveri Company of Switzerland. These three units add 162,000 kilowatts to the capacity of the first 18 units of 436,000 kilowatts, bringing the total to 598,000 kilowatts, by far the largest hydro plant installation in the TVA system.

The authorization, operation, and cost data of the first 18 units of this plant—10 installed by the TVA and 8 in the original construction—are as follows:

Authorization (units 9–18):	
Units 11 and 12	May 9, 1940
Units 9 and 10	August 2, 1940
Units 15 and 16	July 17, 1941
Units 13 and 14	January 15, 1942
Units 17 and 18	May 20, 1947
Commercial operation (units 9–18):	
Unit 12	March 25, 1942
Unit 11	May 5, 1942
Unit 10	July 18, 1942
Unit 9	August 31, 1942
Unit 15	April 22, 1943
Unit 16	November 21, 1943
Unit 13	December 1, 1949
Unit 14	January 6, 1950
Unit 17	February 14, 1950
Unit 18	March 20, 1950
Cost of the 18-unit project (acquired cost to TVA plus cost of TVA improvements exclusive of estimated cost of new lock) including switchyard	$52,047,435

The dam, shown in figure 59, is concrete, gravity type with a 2,668-foot spillway section containing 58 Stoney gates, and a 230-foot nonoverflow and trash chute section. The powerhouse, at the south side of the river, extends for a distance of 1,197.5 feet, including unloading and assembly areas at the shore end. The electrical bay is constructed between the powerhouse and the dam, and above the electrical bay a highway extends across the river, with a bascule bridge over the lock. The control building, switch building, and switchyards are located on the south abutment. An 11-story generator leads tower or riser shaft is built between the powerhouse and control building with stairway, elevator, and riser space. A separate utility building is located south of the switch building. The overall length of the project's continuous structures is about 4,900 feet. Cross sections of the powerhouse units are shown in figure 60.

Turbines

The vertical Francis-type turbines for units 1 to 4, which were manufactured by the I. P. Morris Co. (now Baldwin-Lima-Hamilton Corp.), are rated 30,000 horsepower at 95-foot head and operate at a speed of 100 revolutions per minute. At rated conditions the

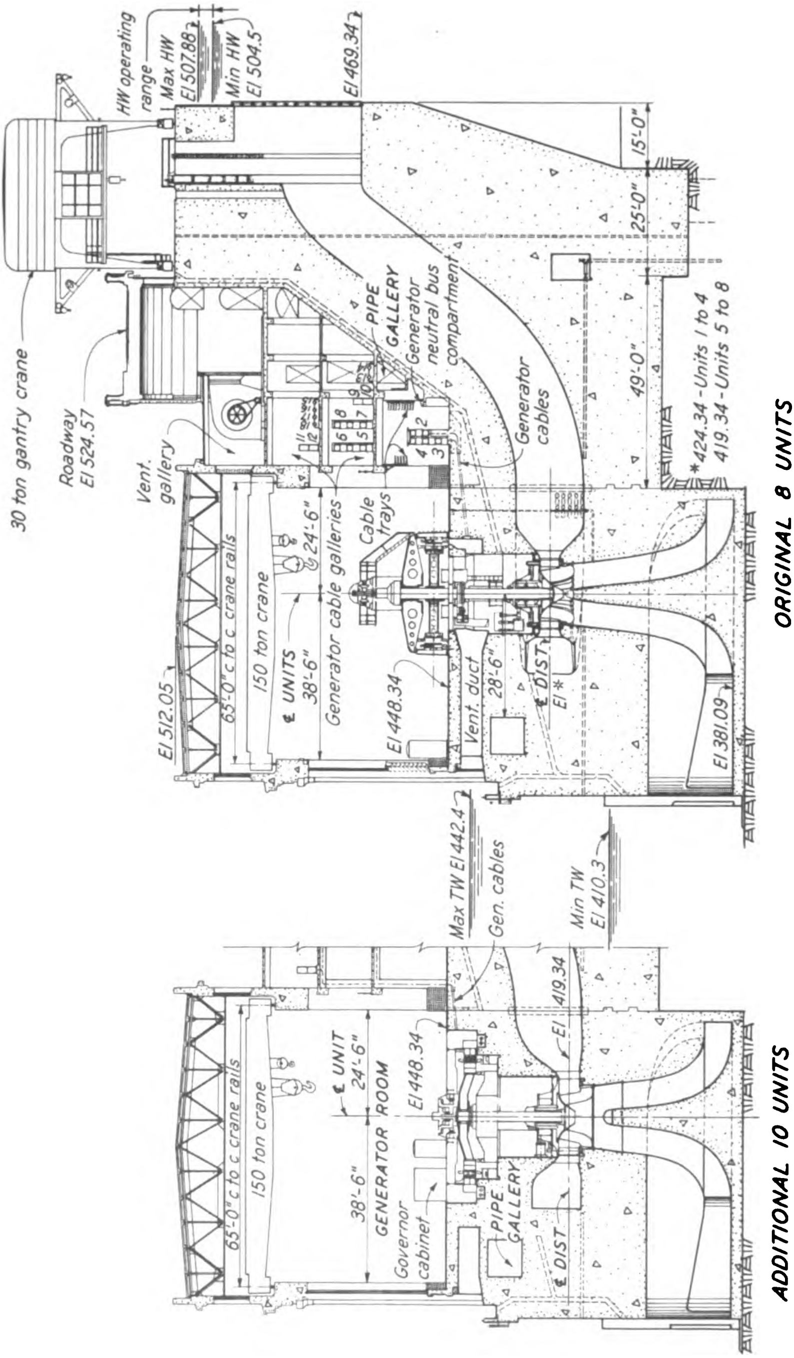

FIGURE 60.—Wilson powerhouse cross sections.

value of specified speed is 58.4 and the center line of the runner is placed about 12 feet above normal tailwater elevation.

The vertical Francis-type turbines for units 5 to 8, which were manufactured by the Newport News Shipbuilding & Dry Dock Co., are rated 35,000 horsepower at 92-foot head and operate at a speed of 100 revolutions per minute. At rated conditions the value of specific speed is 65.8 and the center line of the runner is set about 7 feet above normal tailwater elevation.

The turbines for units 9 to 18 were manufactured by the Allis-Chalmers Manufacturing Co. and installed by TVA. They are vertical Francis type, rated 35,000 horsepower at 92-foot head and operate at a speed of 100 revolutions per minute. They are designed to operate satisfactorily under any net head from a minimum of 68 feet to a maximum of 97.5 feet and withstand a maximum runaway speed of 193 revolutions per minute. At rated conditions the value of specific speed is 66 and the center line of the runner is set approximately 7 feet above normal tailwater elevation, giving a plant sigma of 0.30.

All units have concrete spiral cases with cast-steel stay rings. The cast-steel runners for units 9 to 18 have 15 buckets, and the water to the runner is controlled by 20 wicket grates. The draft tubes for all 18 units were completed during the initial construction of the dam. Unit 1 has an elbow-type draft tube with spiral baffles, unit 3 has a Low Moody spreading cone draft tube, and the other 16 units have High Moody spreading cone draft tubes. The Moody-type draft tube is slightly more efficient than the elbow type; however, TVA has not used the Moody type on any of the plants which it has designed because of the additional cost.

Governors

The governor system for units 1 to 8 is the central automatic-water-pressure type. Each unit is equipped with a Lombard governor and 115-cubic-foot accumulator, with an additional hand control governor stand at units 7 and 8. Three governor fluid 3-stage, turbine-type pumps, rated at 720 gallons per minute at 405-foot head with 150-horsepower, 440-volt induction motors, operate in parallel to supply pressure to the system. With 1 pump as a standby unit, 2 governor fluid pumps are set for automatic operation with 1 pump starting at 140 pounds per square inch and the second at 130 pounds per square inch, both stopping at 150 pounds per square inch. Three fluid tanks with a total volume of 1,740 cubic feet are provided for return fluid.

The governors for units 9 to 18 are the twin cabinet-actuator type manufactured by the Allis-Chalmers Manufacturing Co. Each cabinet houses the governor heads, oil pumps, and auxiliaries for two units and a common sump tank which serves both units. The pressure tanks are located directly behind the actuator cabinet. The governor heads are driven by potential transformers connected to the main generator leads. The oil pumps are the gear type directly connected to 30-horsepower motors and rated at 100 gallons per minute at a pressure of 300 pounds per square inch. Each pressure tank has a volume of 110 cubic feet, and each twin sump tank has a volume of 180 cubic feet.

Estimates have been made for future installation of facilities to provide for remote control of units 9 to 18 from the station control room.

Generators

In the original installation the eight main generators (fig. 61) are vertical, open-frame, air-cooled machines with thrust bearings above the rotors and exciters above the bearings. Units 1 to 4, manufactured by the Westinghouse Electric Corp., are rated 25,000 kilovolt-amperes, and units 5 to 8, manufactured by the General Electric Co., are rated 32,500 kilovolt-amperes. All eight units operate at 0.8 power factor, 12,000 volts, and 100 revolutions per minute.

The 10 additional generators for units 9 through 18 (fig. 62), manufactured by Allis-Chalmers Manufacturing Co. and installed by TVA, have a normal rating of 28,000 kilovolt-amperes or 25,200 kilowatts at 0.9 power factor, 60 cycles, 3 phase, 13,800 volts, and 100 revolutions per minute. The main and pilot exciters are mounted above the main rotor. An enclosed, water-cooled, air-circulating system and CO_2 fire protection are provided. A combination Kingsbury-type thrust bearing and segmental guide bearing, located below the generator rotor, is immersed in an oil reservoir with a capacity of 900 gallons. Cooling coils in the generator bearing oil reservoir are designed for a flow of 25 to 60 gallons per minute of cooling water per unit.

The generators of units 1 to 8 are equipped with air-operated brakes designed for 200-pound-per-square-inch air pressure. The brakes of units 5 to 8 are also used as jacks. The generators of units 9 to 18 are each equipped with six single cylinder units of combined air-operated brakes and oil-operated jacks mounted on the bearing bracket arms, designed for 100-pound-per-square-inch air pressure and 2,100-pound-per-square-inch oil pressure.

An auxiliary power hydro unit with a Westinghouse generator is installed between units 4 and 5. This generator is rated at 937.5 kilovolt-amperes, 750 kilowatts, 0.8 power factor, 3 phase, 60 cycles, 2,300 volts, and 514.3 revolutions per minute.

Oil systems

Units 9 to 18 required the installation of a separate governor and lubricating oil system which was of conventional design. An oil purification room in the abandoned north auxiliary unit section between units 13 and 14 contains 1 clean- and 1 dirty-oil storage tank, each of 3,000-gallon capacity; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; and one 375-gallon-per-hour purifier. A complete piping system supplies and returns oil to the generator bearings and governor sumps.

The insulating oil system consists of storage facilities, pumps, and purifiers located in the utility building, and connecting piping to the electrical equipment in the switchyards. There is also an alumina reactivating tank for acid removal. Three 10,000-gallon clean-oil tanks (1 circuit breaker, 1 transformer, and 1 reserve), an 8,000-gallon dirty circuit breaker oil tank, a 10,000-gallon dirty transformer oil tank, and a 10,000-gallon dirty reserve oil tank

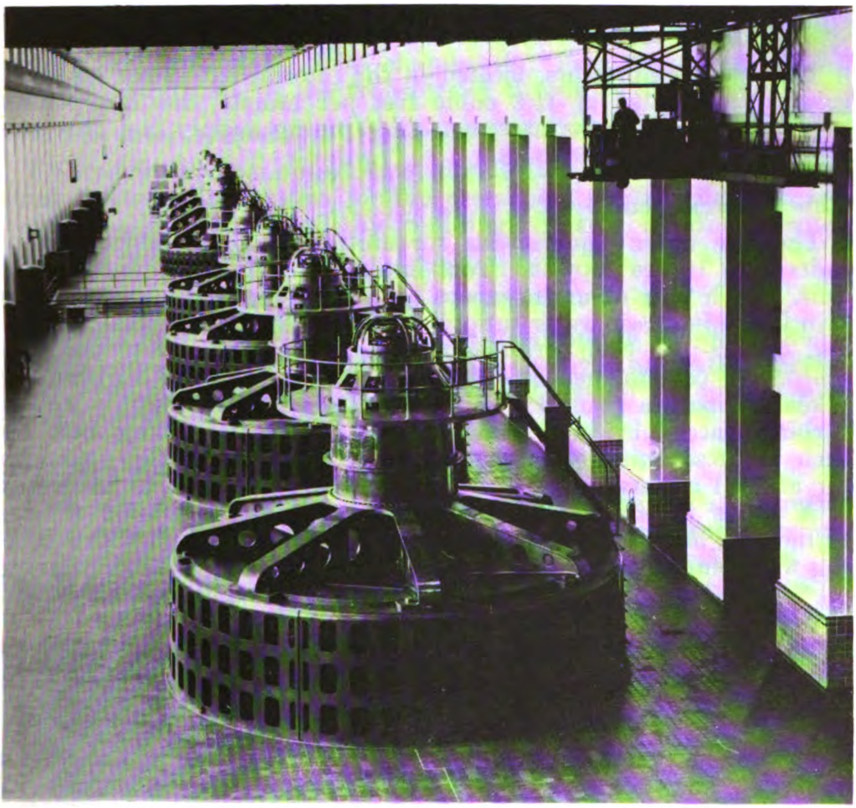

FIGURE 61.—*Wilson generator room—units 1–8 in foreground.*

comprise the storage facilities. Two centrifugal purifiers, a filter press, and necessary transfer pumps are also provided.

Compressed air systems

Two 2-stage air compressors, rated at 660 cubic feet per minute at 100 pounds per square inch and located in the south service bay, provide compressed air for station service. This system is utilized for operation of the generator air brakes and grease compressors of units 9 to 18, and also is the source of air supply for depressing the water level in the draft tube below the runner for these units. In addition, service outlets are installed throughout the powerhouse, spillway, pumphouse, control building, switch building, and utility building.

Three air compressors, located in the intermediate twin governor cabinets and rated at 15.8 cubic feet per minute and 300 pounds per square inch, with interconnecting piping supply the governor air system for units 9 to 18.

Raw water system

The raw water requirements for unit cooling and lubrication of units 9 to 18 are supplied from intakes in the scroll case of each unit. Each pair of units, except units 13 and 14 which have their own individual raw water supply systems, has interconnected intakes and one 12-inch twin strainer, from which the supply to the generator air coolers, generator bearing oil coolers, and turbine are taken. Separate twin strainers are installed in the supply to the turbine water-lubricated bearing, seal ring, and stuffing box for each of these units. The cooling water return from the generator air and oil coolers discharges through a drain header to tailwater.

A series of alarm circuits, operated by flowmeters or flo-sigs to indicate low flow, are provided for units 9 to 18 in the unit cooling water supply lines to the generator air coolers, generator bearing oil coolers, turbine, and turbine bearing. An additional low flow

FIGURE 62.—*Wilson generator room—units 11 and 12 and twin governor cabinet in foreground.*

contact is in the turbine bearing flo-sig to shut down or prevent starting the unit.

Raw water requirements for general station service come from either the pumphouse with intakes in the forebay or the pumping station located on the south shore near the upstream switchyard. Cooling water to the air-conditioning equipment in the control building is supplied by a 250-gallon-per-minute pump in the pump-house, in which is also located two 900-gallon-per-minute pumps discharging to the transformer cooling water header. The pumping station contains two 700-gallon-per-minute pumps and two 3,750-gallon-per-minute pumps which deliver water to the 40,000-gallon tank on the roof of the utility building. The distribution system provides water for lawn sprinklers, transformer cooling, and transformer fire protection. (See chapter 13, "Fire Protection," for a detailed description of the transformer fire-protection system.)

Treated water system

Treated water is supplied from the Wilson Reservation chemical plant treated water system for fire protection, sanitary fixtures, and service outlets in the utility building, control building, switch building, and powerhouse.

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse in the original installation discharged into the river, untreated. Septic tanks were installed later for primary treatment of the sewage with the effluent discharging into the river.

Drainage and unwatering

Unit drainage for units 9 to 18, including seepage water, gutter drains, and wheel pit drains, is collected in drainage sumps which are located between each pair of units except units 13 and 14, which have individual drainage sumps. The drainage sumps at units 13 and 14 are each serviced by 50-gallon-per-minute duplex sump pumps discharging to tailwater through the 12-inch unwatering header. The other four drainage sumps are each serviced by 205-gallon-per-minute duplex sump pumps, also discharging to tailwater.

Each of units 9 to 18 is provided with a 3,000-gallon-per-minute, deepwell, turbine-type unwatering pump which is installed in a pump well adjacent to the draft tube. Each draft tube has a drain outlet connecting to the pump well. The discharge of the pumps for each unit is carried to tailwater through a 12-inch header embedded in the powerhouse substructure. A 12-inch scroll case drain and fill line connects each unit scroll case and draft tube.

Originally, four draft tube gates with hoisting equipment were provided for units 9 to 12, inclusive, to close off flow of tailwater into draft tubes and scroll cases during construction and afterwards during operation whenever it becomes necessary to unwater a unit for inspection or repair. These gates were used for construction purposes only.

After construction it was considered more advantageous to have a floating caisson which could be used for any of units 1 to 18,

inclusive, to close the draft tube opening. This caisson was constructed in the field by using two of the draft tube gates back to back with skin plates on the outside making a watertight caisson. The caisson has two watertight end compartments for ballast and a larger watertight center compartment for sinking the caisson into place wtih an operating platform above tailwater elevation when the caisson is in position at the draft tube opening.

Pumps, valves, and piping are installed in the caisson to admit and expel water ballast necessary to operate caisson. The arrangement is such that the two caisson pumps may be used to assist the draft tube unwatering pumps when unwatering a unit. The same timber seals were used as were on the gates except that two layers of rubber belting were fastened to the outside edge of the timber. This belting laps onto the concrete to help seal the joint.

Fire protection

Three separate automatic CO_2 fire-extinguishing systems were installed in the powerhouse by TVA. All three systems are arranged for remote automatic electrical operation and for local manual operation.

Two identical CO_2 systems, one for units 9 through 13 and the other for units 14 through 18, provide generator fire protection. Each system consists of an initial and a reserve bank containing 18 fifty-pound cylinders each, and a delayed discharge bank of 10 cylinders. The initial bank is arranged for the simultaneous discharge of 18 cylinders to either of the 5 generators in the system. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent cylinder release.

The third system, for protection of the oil purification room in the north service bay, consists of one bank of nine 50-pound CO_2 cylinders arranged for simultaneous discharge.

Portable fire-extinguishing hand units are conveniently located throughout the station.

The transformer water spray fire-protection system is described in detail in chapter 13, "Fire Protection." A supply of treated water, with fire hydrants and hose connections at convenient locations, is used for general fire protection.

Service equipment

The separate utility building was originally designed to accommodate the machine shop equipment as well as other service facilities such as the oil purification equipment. After construction of the Wilson Reservation Power Service Building (ch. 15) the majority of the utility building shop equipment was transferred to the central shops of the new structure.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, load dispatcher's room, offices, and telephone room. The remainder of the switch house building and the powerhouse are mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the

occupants. Electric unit heaters throughout the buildings heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters.

The air-conditioned spaces are served by a combination heating, cooling, and ventilating system complete with fan, electric blast heater, cooling coils, humidifier, filters, air distribution system, piping, and the customary controlling dampers and devices. Cooling and dehumidification are accomplished by circulating chilled water through the cooling coils by the water chilling mechanical refrigeration system. A separate packaged air-conditioning unit serves the telephone room.

CHEROKEE

Cherokee Dam, named for the Cherokee tribe of Indians which at one time inhabited the area, is located at mile 52.3 on the Holston River in the eastern section of Tennessee. This main-tributary project was the first of several TVA dams authorized under the World War II emergency program and was constructed on an emergency basis. Although Congress authorized the completion of 3 units in the original construction, only 2 were initially installed at Cherokee. The third turbogenerator unit and auxiliary equipment which had been purchased for Cherokee were installed at Douglas Dam to take the fullest advantage of power resources as quickly as possible. Authorization, construction, operation, and cost data are as follows:

Authorization:	
Project and units 1, 2, and 3	August 2, 1940
Unit 4	August 10, 1950
Construction started	August 1, 1940
Closure	December 5, 1941
Commercial operation:	
Unit 1	April 16, 1942
Unit 3	June 17, 1942
Unit 2	January 29, 1953
Unit 4	October 7, 1953
Cost of the 4-unit project including switchyard	$36,241,630

A view of the concrete structure looking upstream from the north bank is shown in figure 63. The completed structure, of which the plan, elevation, and sections are shown in figure 10, on page 24, consists of concrete gravity-type spillway, intake, and bulkhead sections, flanked by earth embankments on either side. The total length of the dam is 6,760 feet, exclusive of the saddle dams. The maximum height of the dam from the lower part of the foundation to the spillway deck is 175 feet.

The flow over the spillway, which has a maximum discharge capacity of 256,000 cubic feet per second, is controlled by nine 32- by 40-foot radial gates which are operated by two traveling hoists. Eight sluiceways are provided in the spillway for low water releases.

The powerhouse intake section contains the penstocks, trashracks, gates, and gate hoisting equipment. The powerhouse is a reinforced concrete and structural steel structure of the semioutdoor type with

FIGURE 63.—*Cherokee project.*

a 225-ton gantry crane mounted on the roof. Equipment is handled by the gantry crane through hatches over the units and service bay. The draft tube gates are operated with a jib boom hoist on the powerhouse gantry crane. The electrical bay, control room, and offices spaces are located upstream from the units and over the toe of the intake blocks. Figure 64 shows a sectional elevation of the powerhouse and intake.

The switchyard is located on the north bank of the river adjacent to the powerhouse and downstream from the nonoverflow section of the dam.

Turbines

Four Francis-type hydraulic turbines, manufactured by the S. Morgan Smith Company, are direct-connected to the generators. Figure 65 shows sections of a turbine and generator. The turbines, of which a runner is shown in figure 66, are rated 41,500 horsepower under a net head of 100 feet and operate at a speed of 94.7 revolutions per minute. They are designed to operate under any head from a minimum of 55 feet to a maximum of 146 feet and to withstand a maximum runaway speed of 189 revolutions per minute. At rated conditions the value of specific speed is 61 and the centerline of the runners is set about 5 feet above normal tailwater elevation giving a plant sigma of 0.27.

These units have riveted plate-steel spiral cases and cast-steel stay rings. The cast-steel runners have 15 buckets and the water to the runner is controlled by 20 cast-steel wicket gates. The turbine shaft is guided by an oil-lubricated, babbitt bearing located above the head cover. An alternating-current oil pump supplies oil to the bearing under normal conditions and a direct-current pump is provided which comes into operation automatically in case of failure of the alternating-current pump.

Governors

The governors are the cabinet-actuator type manufactured by the Woodward Governor Co. Units 1 and 2 governors are the twin type, both mounted in a single cabinet, while units 3 and 4 are each equipped with a single actuator cabinet (fig. 67).

Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for remote control of the turbine from the control room. With the installation of units 2 and 4, the necessary alterations were made to provide remote control of all units from the control room. The oil pumps are the herringbone-gear type with a capacity of 150 gallons per minute at 300 pounds per square inch and are driven by 40-horsepower motors. Units 1 and 2 have interconnected oil pressure systems so that both governors may be operated from one oil pump. Units 3 and 4 governors each have two 150-gallon-per-minute pumps, one of which operates as a spare. The pressure tanks are located directly behind the actuator cabinets and each has a volume of 172 cubic feet.

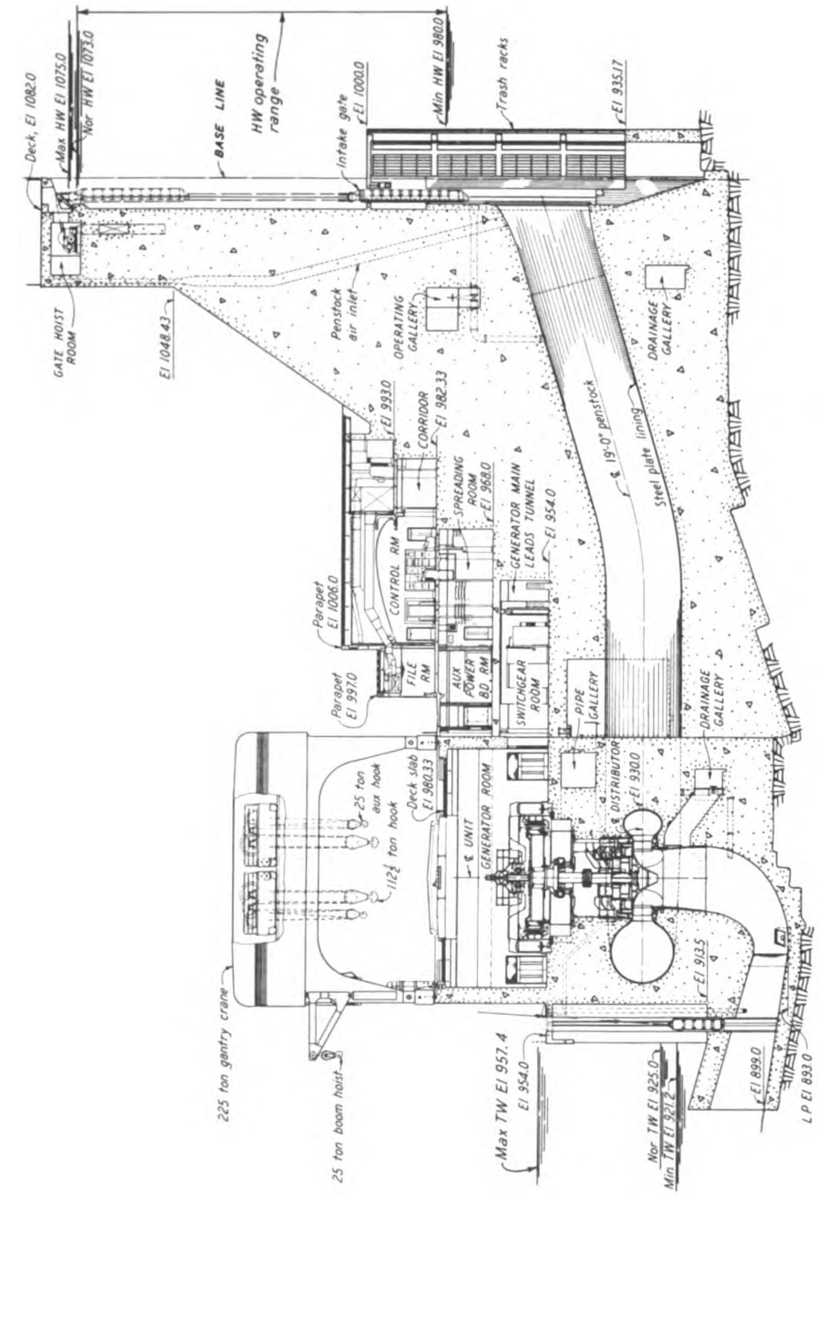

FIGURE 64.—Cherokee—powerhouse and intake section.

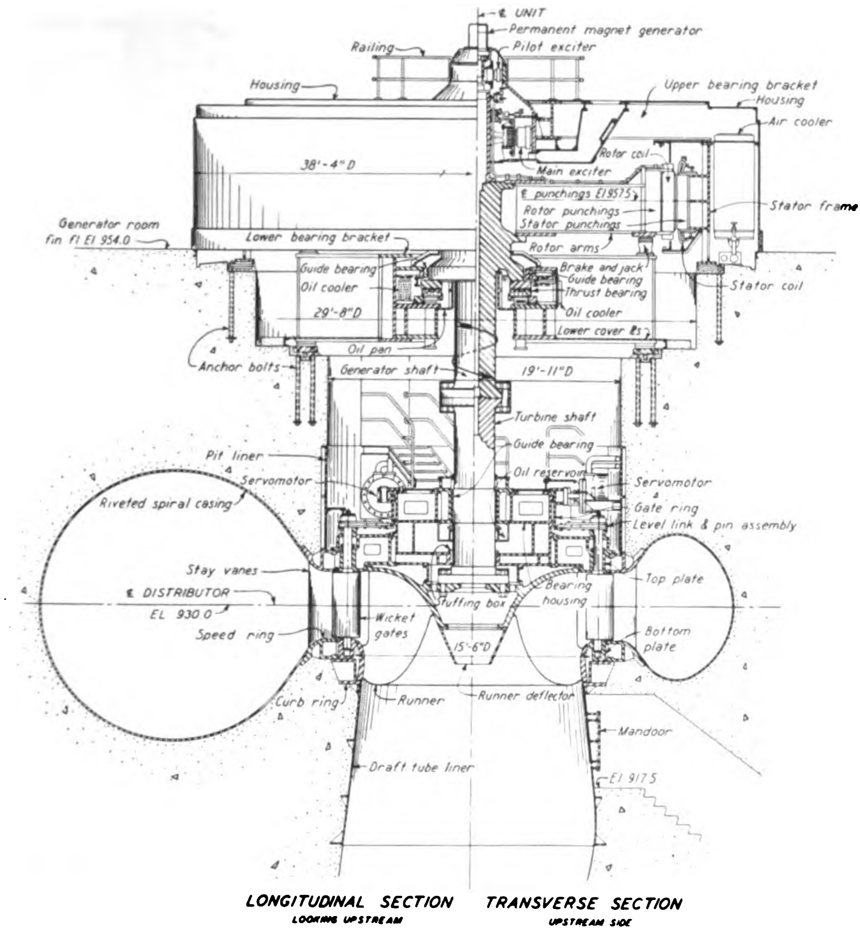

FIGURE 65.—*Cherokee—turbine and generator sections.*

Generators

The four generators, manufactured by the General Electric Co., are the vertical shaft type, totally enclosed and cooled by forced-air circulation through water-cooled heat exchangers within the housing. Each generator has a rated capacity of 33,333 kilovolt-amperes, 30,000 kilowatts, 0.9 power factor, 13,800 volts, and operates at 94.7 revolutions per minute. The rotor is designed for a maximum run-away speed of 190 revolutions per minute.

The generator brake shoes bear on a brake ring mounted under the rotor. Combination brakes and jacks are mounted on the generator bearing bracket, 6 at units 1 and 3 and 4 at units 2 and 4, with 2 separate jacks. Air pressure at 100 pounds per square inch for braking is automatically controlled. Oil pressure at 1,100 pounds per square inch for jacking is applied by means of a portable hand-operated oil pump.

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FIGURE 66.—*Cherokee—Francis turbine runner.*

The combination thrust and segmental guide bearing is below the rotor. The thrust bearing of units 1 and 3 is the Kingsbury type, and of units 2 and 4 the General Electric type. The bearing is immersed in oil, with water coolers provided in the oil reservoir.

A carbon dioxide fire extinguishing system is provided for each generator with nozzles located in ring headers above and below the rotor.

Sections of a generator are shown in figure 65, and a view of the generator room is shown in figure 67.

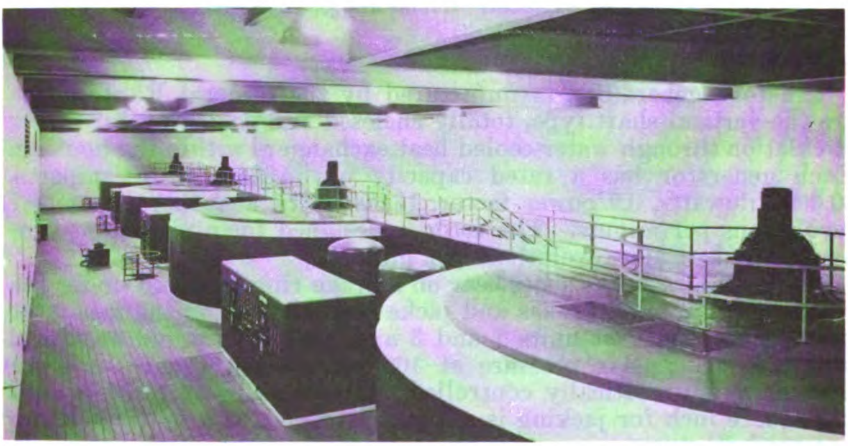


FIGURE 67.—*Cherokee generator room.*

Oil systems

All governor and lubricating oil storage tanks and pumping and purification equipment are located in the basement of the service bay. The lubricating oil storage facilities consist of 1 dirty- and 1 clean-oil tank of 3,660-gallon capacity each. The pumping equipment consists of 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity. The lubricating oil purifier capacity is 350 gallons per hour. A complete piping system for supply and return of lubricating oil to the equipment is provided.

A sluice gates oil pressure system is in the spillway operating gallery. The system consists of two oil pumps (one intended for standby service) rated at 20 gallons per minute at 1,200 pounds per square inch, a 330-gallon-capacity storage tank, and a complete piping system for operation of the sluice gates. In each of the eight sluiceways are an emergency gate and a service gate with hydraulically operated cylinders.

The insulating oil storage tanks and pumping and purification equipment are also located in the basement of the service bay. The transformer and circuit breaker oil storage facilities consist of 2 dirty transformer oil tanks, each of 5,030-gallon capacity, 1 dirty circuit breaker oil tank of 6,420-gallon capacity, and 1 clean insulating oil tank of 6,420-gallon capacity. One 100-gallon-per-minute clean oil pump is provided for filling the electrical equipment in the switchyard by means of hose connections from convenient valve boxes in the piping system. The equipment is drained by gravity through the drain header. The insulating oil purifier has a capacity of 600 gallons per hour without the filter press and 900 gallons per hour with the press.

Compressed air system

A stationary single-stage, double-acting air compressor with a capacity of 105 cubic feet per minute at 100 pounds per square inch is in the service bay to supply station service and generator air brake requirements. A complete piping system with service outlets is provided. The system includes a 197-cubic-foot air receiver and a water-cooled aftercooler. Air pressure in the system is automatically maintained by a pressure governor.

Compressed air for draft tube evacuation comes from the station service air system. A 2-inch supply line to each turbine wheel pit is provided for manual application of air to the head cover to depress the water level in the draft tube below the runner and allow the units to be operated as synchronous condensers. Depression of the water level is necessary only during periods of high tailwater since the runners are normally above tailwater.

A portable air-cooled motor-driven air compressor of 105-cubic-foot-per-minute capacity at 100-pound-per-square-inch pressure is available for general service.

Compressed air for the governor system is supplied by an 8-cubic-foot-per-minute compressor, complete with piping system, operating at 300-pound-per-square-inch pressure.

Raw water system

Intakes in the penstocks of units 1, 2, and 3 supply raw water to the system. The water flows by gravity through twin strainers to

the generator air and oil coolers, turbine stuffing box and runner seals, gas-electric generator cooling system, station air compressor and aftercooler, and air-conditioning condenser.

A series of alarm circuits, operated by flowmeters or flo-sigs to indicate low flow are provided in the cooling water supply lines to the generator air coolers, the generator bearing oil coolers, and the turbine. An additional contact to shut down or prevent starting the unit on low flow is on the flowmeters in the supply to the generator bearing oil coolers and the turbine.

The unit cooling water supply lines are equipped for manual electric remote control from the control room. Flow through the generator air coolers is automatically controlled by a motor-operated, thermostatically controlled proportioning valve.

Treated water system

Treated water for the powerhouse and switchyard is supplied from Mills Spring, located south of the dam. The water is treated by filtration and chlorination in the filter plant and pumphouse, which contains the following equipment: two Calgon feeders, one alum solution feeder, two chlorinators, one 120-inch pressure filter, one 150-gallon-per-minute filter pump, and two 150-gallon-per-minute service pumps. The water is then pumped to a 50,000-gallon elevated steel storage tank on the left bank and flows through a main to the powerhouse service bay, at which point the supply branches into two systems. The pressure is reduced to 75 pounds per square inch in one system supplying the sanitary plumbing fixtures and 1-inch service outlets and fire protection in the powerhouse. The other system supplies water to the fire hydrants in the switchyard at full pressure.

Sewage disposal

The sanitary waste from the toilet facilities in the powerhouse discharges into a 2,000-gallon septic tank located in the mass concrete of the service bay below the floor at elevation 938. Under normal conditions of tailwater, the effluent from the tank drains directly to the tailrace by gravity through an outlet in the unit 1 draft tube pier at elevation 920.02. When tailwater rises above elevation 930 the effluent from the tank is diverted to the station sump located adjacent to the septic tank from where it will automatically be discharged to tailwater by the drainage pumps.

The sanitary waste from the toilet facilities in the public safety service headquarters and public toilet building located near the boat harbor discharges into a 2,000-gallon concrete septic tank approximately 100 feet west of the building. The septic tank is provided with a siphon, and the effluent is discharged into a subsurface tile field.

Drainage and unwatering

All powerhouse, spillway, and intake drainage below normal tailwater elevation discharges directly into the station drainage and unwatering sump located in the basement of the service bay. Powerhouse drainage above tailwater elevation normally discharges directly to the tailrace, but may be bypassed to the sump during periods of

high tailwater. Roof and deck drains discharge directly to the tailrace.

The working capacity of the sump is 20,500 gallons. Normal drainage is pumped to the tailrace by two 300-gallon-per-minute, deepwell, turbine-type pumps with vertical motors mounted on the basement floor of the service bay. Operation of the station drainage pumps is automatic, and the draft tube unwatering pump is available for manual operation in case of emergency.

A drain and equalization line connects the spillway drainage gallery to the sump. Drainage is normally discharged to the sump. If an excessive amount of leakage accumulates in the gallery during high water conditions it may be necessary to allow the gallery to fill to tailwater level. If this condition exists, the proper valves are operated to permit the excess leakage to equalize to the tailrace, preventing any pressure or uplift upon the spillway structure greater than that caused by tailwater. A second equalization line is provided from the spillway gallery at the left training wall with valves set to equalize excess leakage to tailwater automatically. This method of equalizing accumulated leakage to the tailrace also guards against the possibility of exceeding the sump pumping capacity which might flood portions of the powerhouse.

Each draft tube has a screened outlet approximately 1 foot above the low point of the draft tube, and a 12-inch drain with a control valve was installed to connect each draft tube to the station drainage and unwatering sump. The drain valves for all scroll cases are operated from the powerhouse drainage gallery. The drain valves for units 2, 3, and 4 draft tubes are located in the valve well between units 2 and 3 and are operated from the drainage gallery. The drain valve for unit 1 draft tube is operated from the service bay floor directly above the sump. Two 3,000-gallon-per-minute, deepwell, turbine-type pumps are provided for unwatering. The pumps are manually controlled and may be used to augment the station drainage pumping capacity.

Fire protection

There are two separate CO_2 fire-extinguishing systems, each arranged for local manual or automatic remote control. The carbon-dioxide fire-protection system for the generators consists of three banks of 50-pound cylinders, an initial discharge and a reserve bank of 20 cylinders each, and a delayed discharge bank of 14 cylinders. The initial bank is arranged for the simultaneous discharge of the entire bank to any generator. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent release.

The other carbon-dioxide fire-extinguishing system protects the oil storage, oil purification, and gas-electric generator rooms, and consists of 1 bank of 18 cylinders. The system is arranged for release of nine cylinders into either the oil purification room or the gas-electric generator room, or for release of the entire bank into the oil storage room.

Portable fire-extinguishing units are conveniently located in the powerhouse and switchyard. One 100-pound wheel-type carbon dioxide unit is located in the switchyard.

A supply of treated water with fire hydrants and hose connections at convenient locations is provided for general fire protection in the powerhouse and switchyard.

Service equipment

The machine shop, which is of conventional size and located in a separate room in the service bay adjacent to the erection bay, contains the equipment as listed in table 14, page 626.

An automatic push button-controlled elevator, which has a live load capacity of 5,000 pounds at a speed of 250 feet per minute, is installed in the dam for the use of operating personnel. The elevator has a total lift of 100 feet with a bottom landing in the corridor from the powerhouse control room, an intermediate landing at the intake gate hoist gallery, and a top landing at the intake deck level. Design data covering this machine are included in table 6, page 394.

The emergency auxiliary power generating unit, which is installed in the electrical bay adjacent to the machine shop, has a 200-kilovolt-ampere, 0.8 power factor, 3-phase, 60-cycle, 480-volt generator with direct-connected exciter, driven by a 290-brake-horsepower, 8-cylinder, 1,200-revolution-per-minute engine.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, public spaces, telephone room, first-aid room, and offices. The remainder of the powerhouse is mechanically ventilated. Electric unit heaters located throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters serve to supplement the permanently connected heaters.

The air-conditioning spaces are served by four combination heating, cooling, and ventilating systems, each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system. The mechanical water chilling system can be bypassed and lake water used whenever the temperature of the water will provide sufficient cooling.

Ventilating, heating, and air-conditioning design requirements are summarized as follows:

Cubic feet per minute of air supplied and exhausted	228,900
Kilowatts of installed electric heating	543
Horsepower of refrigeration	75

DOUGLAS

Douglas Dam, on the French Broad River at mile 32.3 and 26 air miles east of Knoxville, was constructed as part of the third World War II emergency program. Following a long controversy with agricultural interests in the French Broad Valley, which contributed to the support of a large canning industry, TVA's recommendation for the construction of the Douglas project as the most desirable addition to the system for combined power and flood control purposes was approved. With the declaration of war in December 1941, the demand for an increased supply of electricity to become available in 1943 required the immediate construction of Douglas Dam.

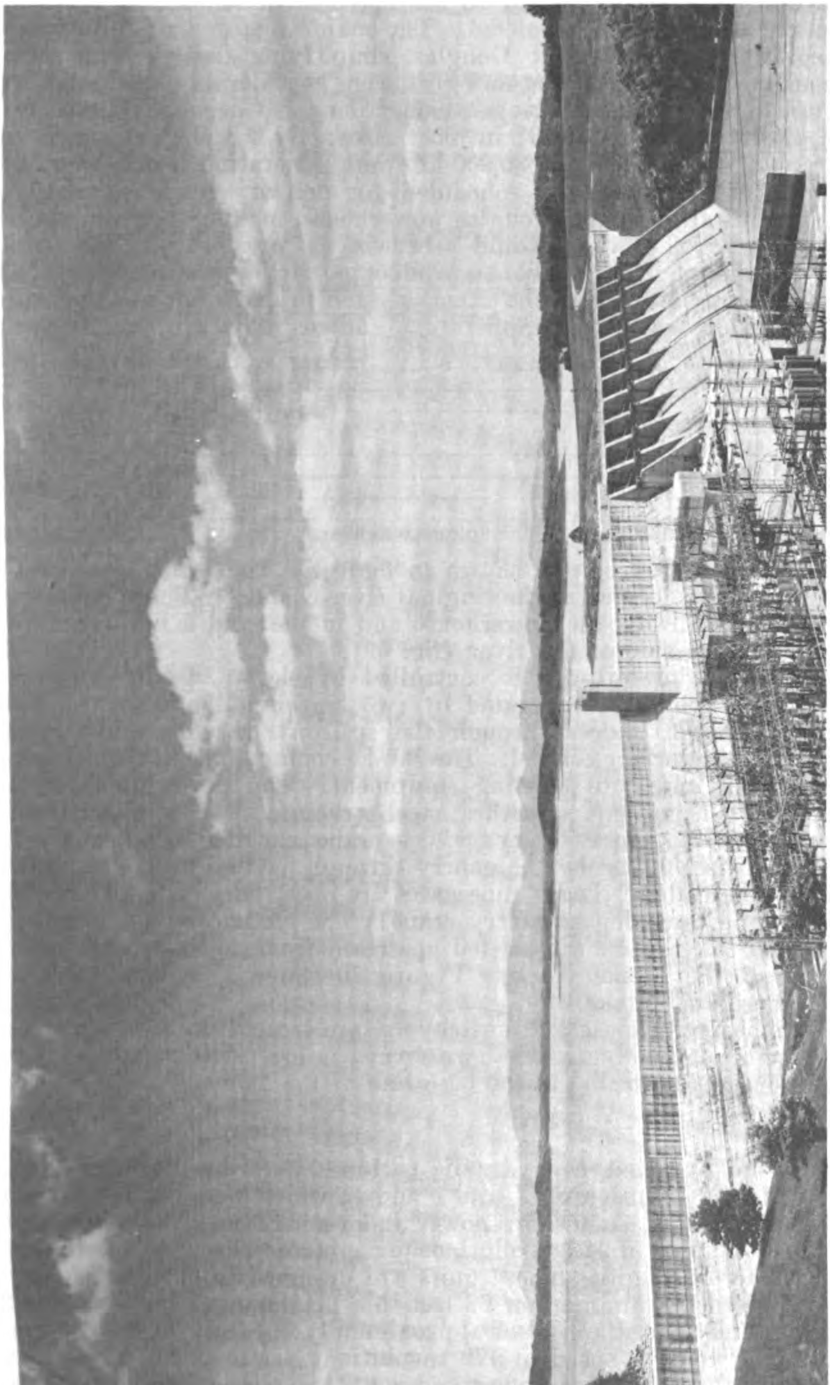


FIGURE 68.—*Douglas project.*

Several factors contributed to the speed with which this main-tributary project was completed. The major features of Cherokee project were duplicated at Douglas, simplifying design and procurement. The design time and cost were considerably reduced by the use of reproduced tracings made from the Cherokee drawings with alterations as required; in most cases only the elevations were corrected. In addition, a 30,000-kilowatt generating unit already ordered for Cherokee and scheduled for delivery in March 1942 could be installed in the Douglas powerhouse, making power available a year earlier than would otherwise be possible. These and other factors made it possible to produce power less than 14 months after construction started the same day the project was authorized. Authorization, construction, operation, and cost data are as follows:

Authorization	February 2, 1942
Construction started	February 2, 1942
Closure	February 19, 1943
Commercial operation:	
Unit 3	March 21, 1943
Unit 1	January 12, 1944
Unit 2	May 22, 1949
Unit 4	August 3, 1954
Cost of the 4-unit project, including switchyard	$45,550,914

The completed structure, shown in figure 68, consists of concrete gravity sections located in the original river channel. These sections include the spillway, the powerhouse and intake, and a nonoverflow section on each side of the river (fig. 69).

Flow over the spillway is controlled by eleven 32- by 40-foot radial gates which are operated by two traveling hoists of 60-ton capacity. Eight sluices through the spillway provide additional capacity for reservoir control. The intake contains penstocks, trashracks, gates, and gate hoisting equipment. The powerhouse is a reinforced concrete and structural steel structure of the semioutdoor type with a 225-ton capacity gantry crane mounted on the roof. Equipment is handled by the gantry through hatches over the units and the service bay. Draft tube gates are operated with a jib boom hoist on the powerhouse gantry crane. The electrical bay, control room, and office spaces are located upstream from the units and over the toe of the intake blocks. Figure 70 shows a section of the powerhouse and intake.

Both the powerhouse and switchyard are located on the right or north bank of the river. The switchyard is located adjacent to the powerhouse and parallel to the base line of the dam.

Turbines

The four Francis-type hydraulic turbines were manufactured by the S. Morgan Smith Co. Units 1 and 3, which were the first two installed, are rated 41,500 horsepower under a net head of 100 feet and operate at a speed of 94.7 revolutions per minute. They are identical to the Cherokee units. These units are designed to operate under any head from a minimum of 62 feet to a maximum of 130 feet and to be most efficient at a head of approximately 110 feet. They have a maximum runaway speed of 179 revolutions per minute. At rated conditions the value of specific speed is 61, and the center line of the runner is set about 3 feet above normal tailwater elevation giving a plant sigma of 0.29.

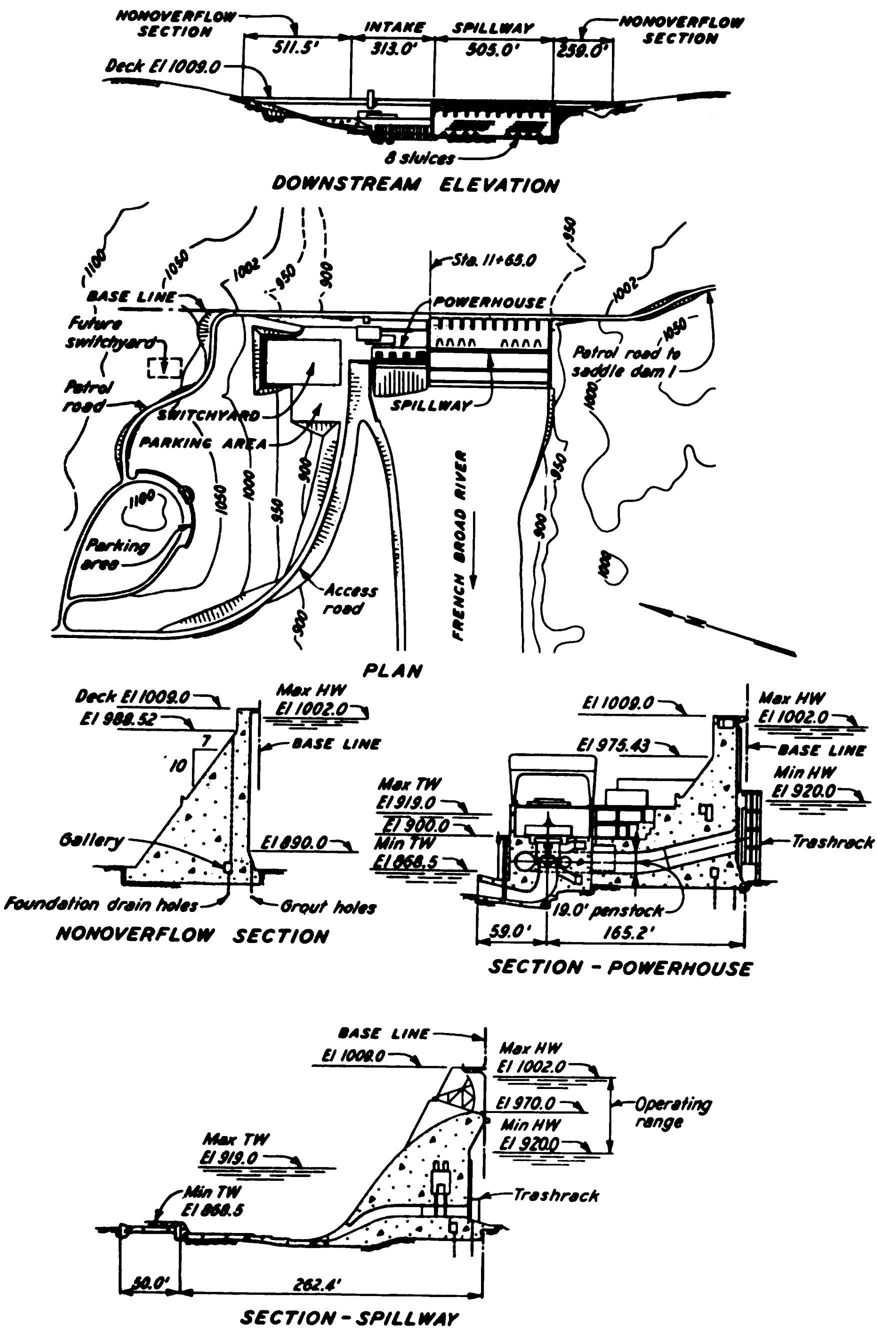


FIGURE 69.—*Douglas—plan, elevation, and sections.*

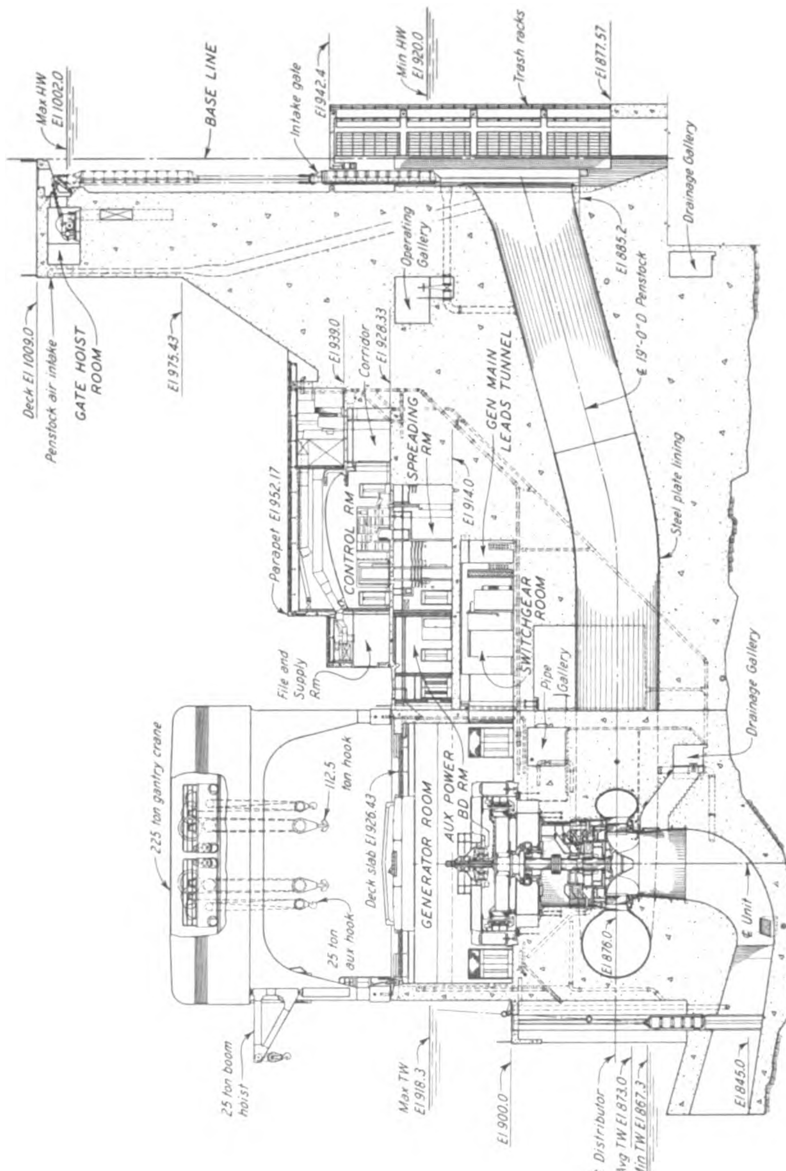


Figure 70.—*Douglas powerhouse and intake section.*

At the time that the third unit (unit 2) was purchased it was decided that the turbines for units 2 and 4 should have a higher specific speed than units 1 and 3 in order to obtain more efficient operation and greater power output under the lower heads existing during the winter months. Consequently, the turbines for units 2 and 4 are rated 35,500 horsepower under a net head of 80 feet and operate at a speed of 90 revolutions per minute. They are designed to operate under any head from a minimum of 47 feet to a maximum of 130 feet and to be most efficient at a head of approximately 88 feet. They have a maximum runaway speed of 191.5 revolutions per minute. At rated conditions the value of specific speed for these units is 70.9, and the center line of the runners is set 3 feet above normal tailwater elevation giving a plant sigma of 0.42.

All four units have riveted plate-steel spiral cases and cast-steel stay rings. The cast-steel runners each have 15 buckets and the water to the runner is controlled by 20 cast-steel wicket gates. The turbine shaft is guided by an oil-lubricated, babbit bearing located immediately above the head cover. An alternating-current oil pump supplies oil to the bearing under normal conditions and a direct-current pump is provided which comes into operation automatically in case of failure of the alternating-current pump to supply sufficient oil to the bearings.

A view of a Francis runner being lowered into the wheel pit is shown in figure 71. The index test conducted on unit 3 is included in appendix A.

Governors

The governors are the cabinet-actuator type, manufactured by the Woodward Governor Company. Units 1 and 2 governors are the twin type, both mounted in a single cabinet, while units 3 and 4 are each equipped with a single actuator cabinet (fig. 72).

With the installation of unit 4, the necessary alterations were made to provide remote control of all units from the control room. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for remote control of the turbine from the control room. The oil pumps are the herringbone-gear type with a capacity of 150 gallons per minute at 300 pounds per square inch and are driven by 40-horsepower motors. Units 1 and 2 have interconnected oil pressure systems so that both governors may be operated from one oil pump. Units 3 and 4 governors each have two 150-gallon-per-minute pumps, one of which operates as a spare. The pressure tanks are located directly behind the actuator cabinets, and each has a volume of 172 cubic feet (fig. 72).

A load rejection test report conducted on unit 4 is given in appendix A.

Generators

The four generators (fig. 72), manufactured by the General Electric Co., are enclosed, water-cooled, vertical shaft type units. The generators for units 1 and 3 are rated 33,333 kilovolt-amperes, 30,000 kilowatts, 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and 94.7 revolutions per minute. The generators for units 2 and 4 are

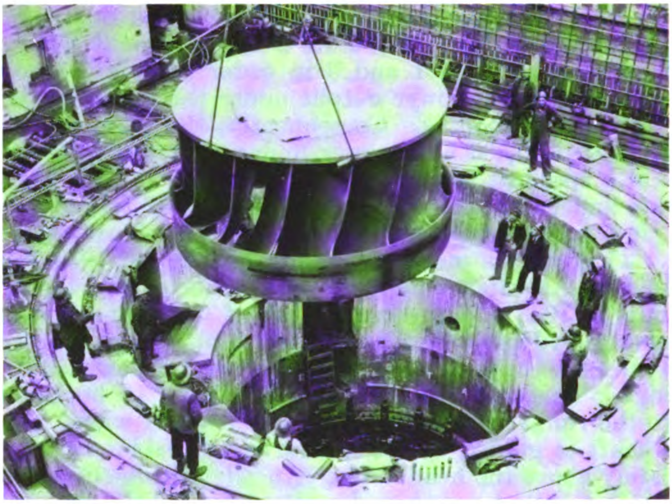


FIGURE 71.—*Douglas—lowering Francis runner into wheel pit.*

rated 28,888 kilovolt-amperes, 26,000 kilowatts, 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and 90 revolutions per minute. The exciters are direct-connected above the rotor.

Heat losses within the generator are removed by forced-air circulation through eight coolers arranged for circumferential flow of air, which returns over the top of the stator and through the bottom of the stator wrapper plate for recirculation.

A combination thrust and guide bearing located below the rotor is immersed in an oil reservoir. The generator bearing oil is cooled by cooling coils circulating raw water through the oil reservoir. Units 1, 2, and 3 are equipped with Kingsbury type thruts bearings, and unit 4 has the General Electric type.

The generator brake shoes bear on a brake ring mounted under the rotor. Six combination brakes and jacks are provided for units 1

FIGURE 72.—*Douglas 4-unit generator room.*

and 3, and 4 with 2 separate jacks are provided for units 2 and 4. Air pressure for braking is automatically controlled. Oil pressure for jacking the rotor is applied by a portable hand-operated oil pump when required.

Initial and delayed discharges of carbon dioxide are available for fire protection of the estimated 14,000 cubic feet of air space within the generator. Nozzles are located in ring headers above and below the rotor.

Miscellaneous services and equipment

Since the Douglas project was in most respects a duplicate of the Cherokee project from the standpoint of mechanical design, the following piping systems, services, and equipment are essentially the same:

- Governor and lubricating oil system
- Sluice gate oil system
- Insulating oil system
- Compressed air systems
- Drainage and unwatering systems
- Fire protection
- Elevator (except with a total lift of 81 feet)
- Machine shop equipment
- Auxiliary power generator
- Heating, ventilating, and air conditioning

Raw water system

The raw water system is essentially the same as Cherokee raw water system with the exception that intakes are provided in the penstocks of all 4 Douglas units instead of only 3.

Treated water system

All treated water for the powerhouse and switchyard is supplied from a spring located on the right bank of the river. A combined springhouse and pumping station was constructed to prevent the water from becoming contaminated and to house two 60-gallon-per-minute pumps, a meter, reagent tanks, and three hypochlorinators. For a detailed description of this treatment plant, refer to chapter 9, "Water-Treatment Systems."

The minimum recorded flow from the spring is 85 gallons per minute. The water is pumped to a 50,000-gallon steel storage tank and flows through the switchyard to the powerhouse service bay. Four-inch branch connections in the switchyard supply the three five hydrants. The entire powerhouse treated water system is reduced to 75-pound-per-square-inch pressure in the service bay for supply to the sanitary fixtures, 1-inch service outlets, and fire hose racks in the powerhouse. One branch line at unreduced pressure is continued through the spillway and intake drainage gallery to the left bank where it can be extended for any future developments.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 2,000-gallon septic tank located in the mass concrete of the service bay below the floor at elevation 884. Under normal conditions of tailwater, the effluent from the tank drains directly into the

tailrace by gravity through an outlet in unit 1 draft tube pier at elevation 866.02. When tailwater rises above elevation 876, the effluent is diverted to the station sump located adjacent to the septic tank, from which it will automatically be discharged to tailwater by the drainage pumps.

The sanitary waste from the toilet facilities in the maintenance building discharges into a 540-gallon concrete septic tank located 8 feet south of the building. The effluent from the tank discharges into a subsurface tile field.

OCOEE NO. 3

The Ocoee No. 3 project, of which the powerhouse, surge tank, valve house penstock, and switchyard are shown in figure 73 and the dam in figure 74, was constructed as part of the World War II emergency program. The project develops 11 miles of the Ocoee River from the powerhouse to the upper reaches of the reservoir to obtain a maximum gross head of 316 feet. The dam is on the Ocoee River, a tributary of the Hiwassee River, at river mile 29.2 and is joined to the powerhouse by a 13,000-foot-long conduit. The Ocoee No. 3 Reservoir provides 9,370 acre-feet of useful storage capacity between minimum and maximum headwater levels, which is utilized to iron out peak discharges from Blue Ridge Reservoir, a hydroelectric project immediately upstream. Authorization, construction, operation, and cost data are as follows:

Authorization	July 17, 1941
Construction started	July 17, 1941
Closure	August 15, 1942
Commercial operation	April 30, 1943
Cost of single-unit project, including switchyard	$8,722,466

As indicated in the plan, elevation, and sections of figure 75, the project consists of a dam, a conduit, a powerhouse, and a switchyard. The dam is a concrete gravity-type structure with a crest length of 612 feet and a maximum height of 110 feet from the foundation to deck level, consisting of nonoverflow, spillway, and intake sections. Seven 23- by 32-foot radial gates in the spillway designed for a maximum flood of 117,000 cubic feet per second and two 5- by 7-foot sluice openings through the dam provide stream control. Individual hoists are mounted on the bridge above the spillway piers for operation of the spillway gates. The tunnel intake is on the left abutment adjacent to the upstream face of the nonoverflow section. The sluice openings are designed to allow silt removal through the dam and are controlled by two slide gates. Two openings, which are covered by reinforced concrete bulkheads, are provided through the dam section for possible future construction of a desilting basin. An operator's room and a gas-electric generator room are located at the extréme right end of the dam.

The conduit from intake to powerhouse is a concrete-lined tunnel for most of the 13,000-foot length. The final 408 feet of the conduit is an 11-foot-diameter exposed steel penstock to the powerhouse. At the head of the penstock and at the lower portal of the tunnel is a valve house (fig. 76) enclosing a 12-foot-diameter butterfly valve for control of flow in the penstock. A differential surge tank is located 133 feet upstream from the valve house.

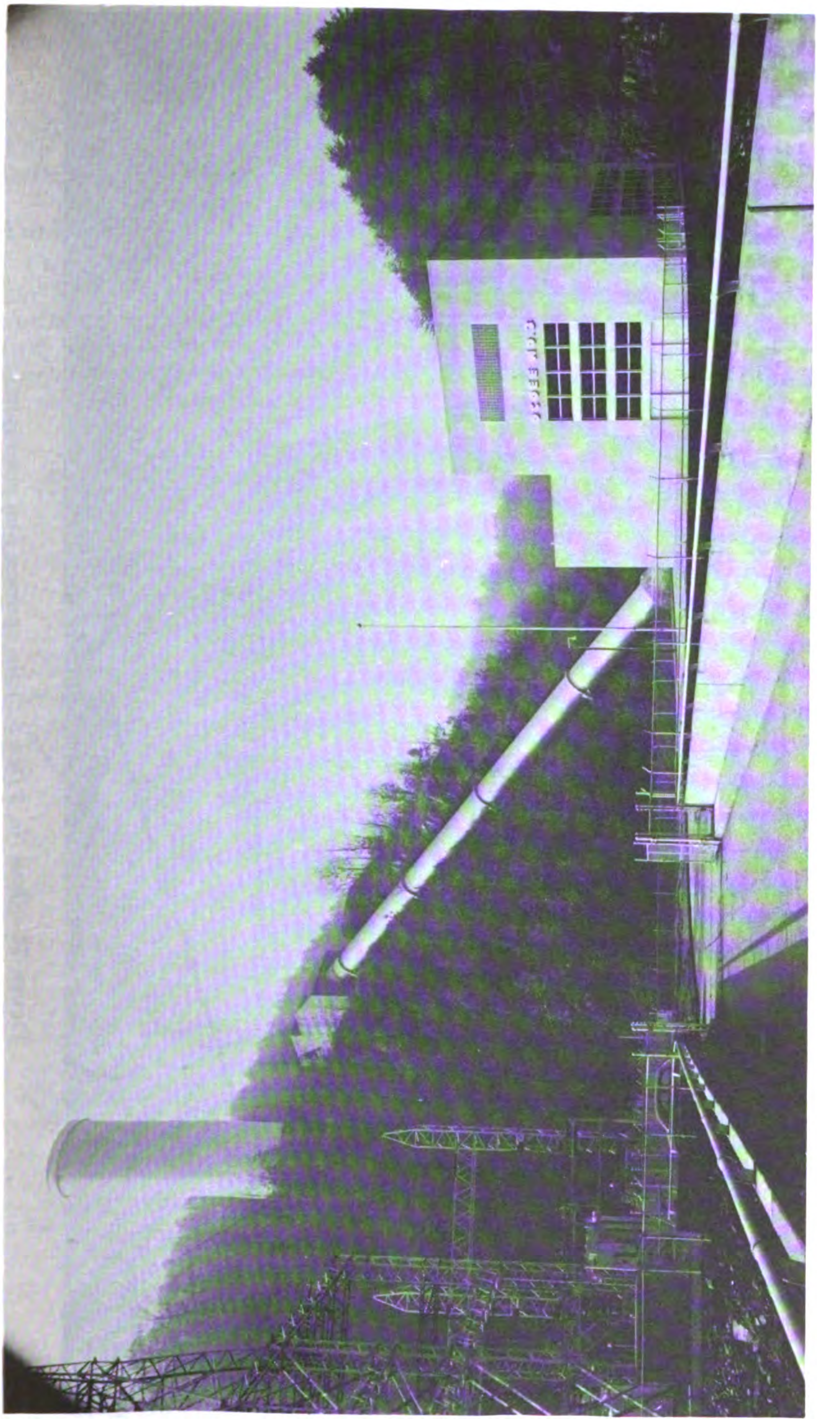


FIGURE 73.—*Ocoee No. 3 switchyard, surge tank, valve house, penstock, and powerhouse.*

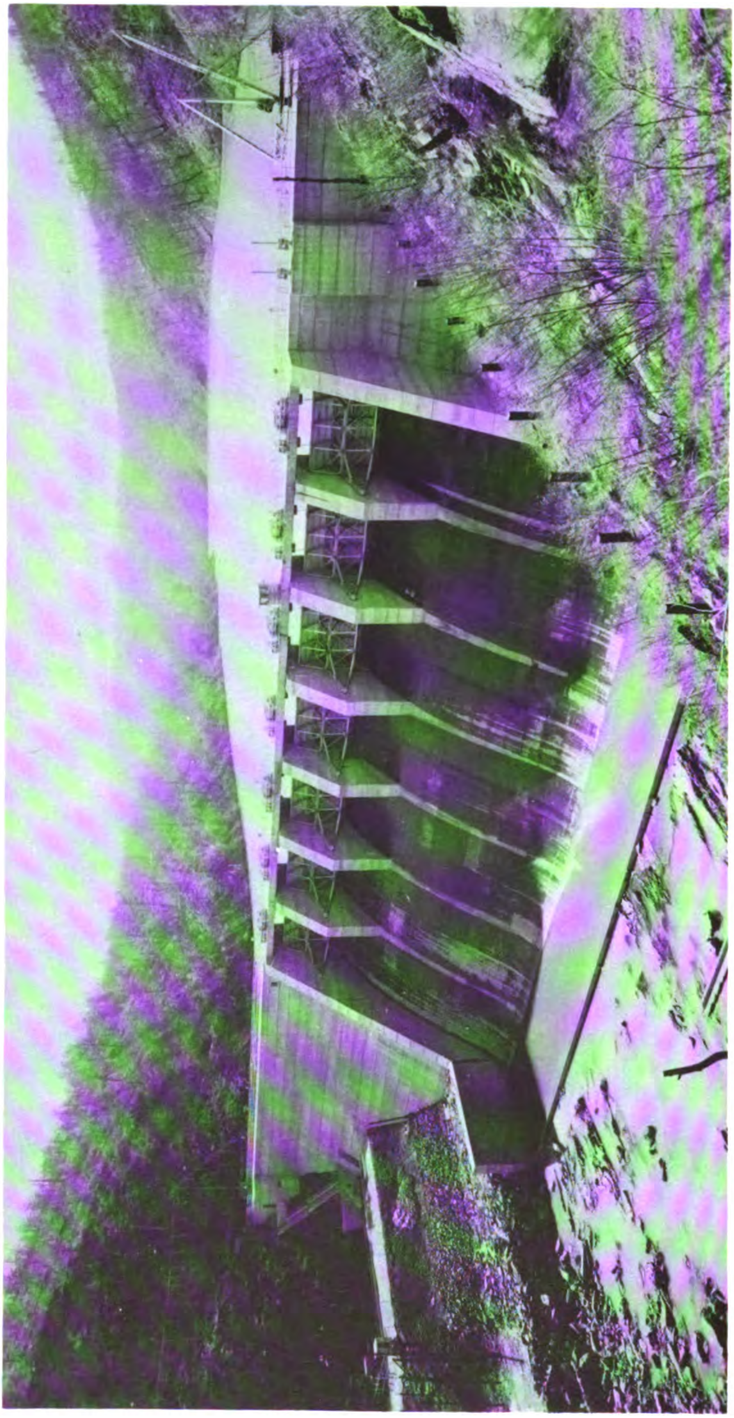


FIGURE 74.—*Ocoee No. 3 Dam 5.2 miles upstream from powerhouse.*

The powerhouse is the fully enclosed type with superstructure of structural steel and limestone exterior, enclosing a generator room, a crane support, and a 3-story equipment bay. A section through the powerhouse is shown in figure 77. The single unit is equipped with remote control for operation from Ocoee No. 2 powerhouse. The switchyard is located upstream from the powerhouse on a fill built up of rock from tunnel excavation.

Turbine

One vertical Francis-type hydraulic turbine, manufactured by the S. Morgan Smith Co., is direct-connected to the generator. The turbine is rated at 33,500 horsepower under a net head of 280 feet and operates at a speed of 200 revolutions per minute. It is designed to operate satisfactorily under any head from a minimum of 250 feet to a maximum of 297 feet and is most efficient at a

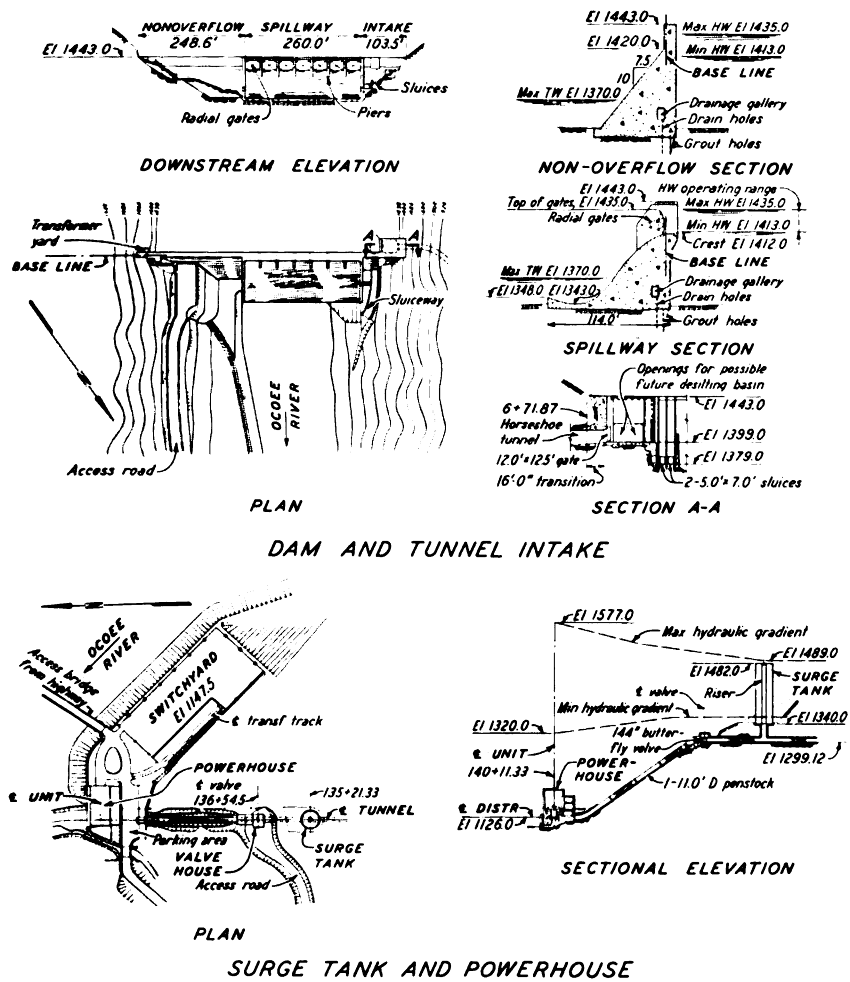


FIGURE 75.—*Ocoee No. 3—plan, elevation, and sections.*

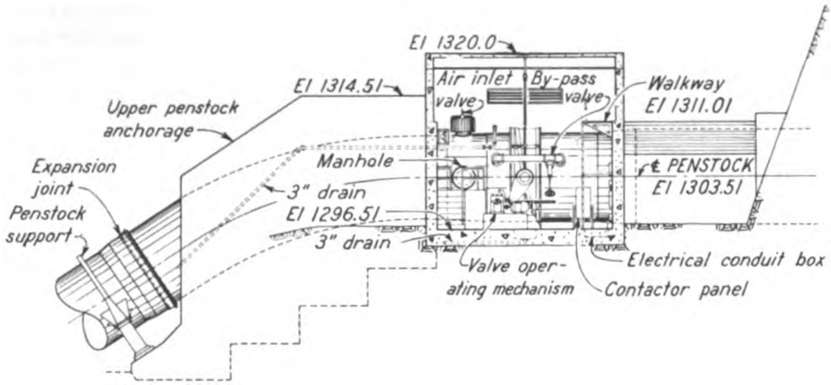


FIGURE 76.—*Ocoee No. 3—butterfly valve house.*

head of approximately 280 feet. It has a maximum runaway speed of 370 revolutions per minute. At rated conditions the value of specific speed is 32, and the centerline of the runner is set about 7 feet above normal tailwater elevation, giving a plant sigma of 0.089.

The unit has a riveted plate-steel spiral case and a cast-steel stay ring which forms the main foundation ring for the turbine. The runner is a 1-piece steel casting with 16 buckets, and the water to the runner is controlled by 18 steel wicket gates. The turbine shaft is guided by an oil-lubricated babbit bearing located above the head cover. An alternating-current oil pump supplies oil to the bearing under normal conditions and a direct-current pump is provided

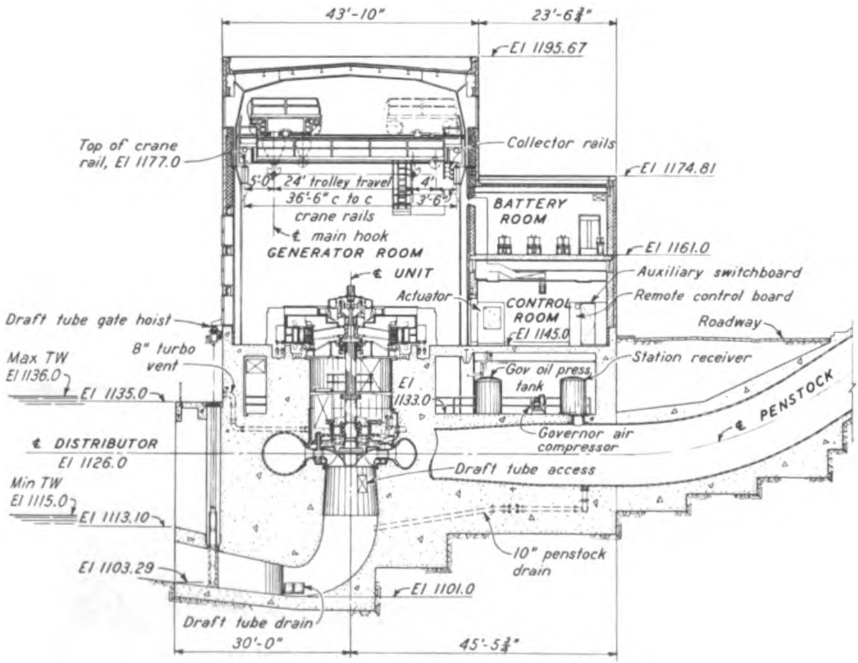


FIGURE 77.—*Ocoee No. 3 powerhouse cross section.*

which comes into operation automatically in case of failure of the alternating-current pump to supply the bearing with sufficient oil.

Transverse and longitudinal sections of the unit are shown in figure 78.

Governor

A single cabinet actuator-type governor, manufactured by the Woodward Governor Co. is installed for the unit. The governor is complete with governor head, sump tank, pressure tank, oil pumps, permanent magnet generator, and the necessary auxiliaries for remote control of the unit from the Ocoee No. 2 powerhouse. The two herringbone-gear-type oil pumps, each with a capacity of 75 gallons per minute at 300 pounds per square inch, are driven by two 20-horsepower motors. One of these pumps supplies oil to the pressure tank, and the other operates as a spare. The pressure tank is located directly behind the actuator and has a volume of 78 cubic feet.

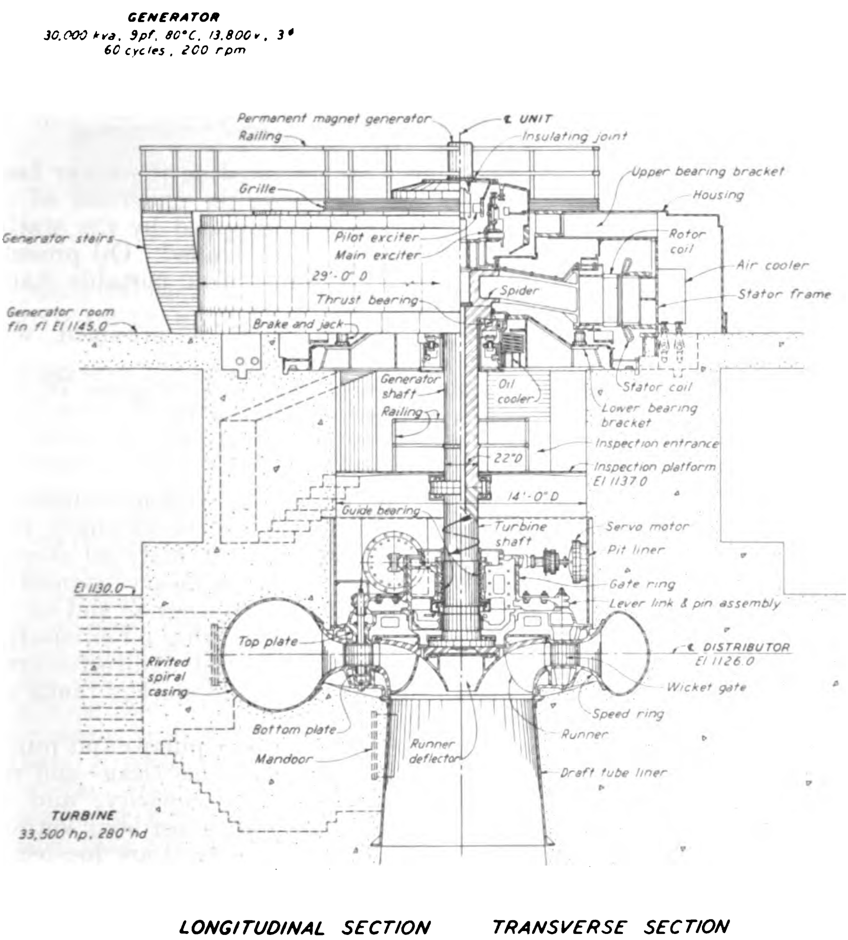


Figure 78.—*Ocoee No. 3—turbine and generator sections.*

Butterfly valve

A 144-inch-diameter butterfly valve, manufactured by the S. Morgan Smith Co., is in the penstock upstream of the spiral case. The valve is equipped with a 25-horsepower motor and is set for a closing time of 60 seconds. The clear opening through the valve with the gate wide open is 80 percent of the valve area and the leakage at 175-foot head is guaranteed not to exceed 4 gallons per minute. Figure 76 is a sectional elevation of the butterfly valve house and penstock.

Generator

The generator, manufactured by the Westinghouse Electric Corp., has a rated capacity of 30,000 kilovolt-amperes or 27,000 kilowatts at 0.9 power factor, 13,800 volts, and operates at 200 revolutions per minute. The vertical shaft type generator is totally enclosed and air cooled with water-cooled heat exchangers within the housing. The quantity of water required by the air coolers is automatically controlled by a thermostatically controlled motor-operated proportioning valve. The combination Kingsbury type thrust and segmental guide bearing located below the rotor is immersed in an oil reservoir which is maintained at a suitable temperature by water coolers. The exciters are mounted on the upper bracket and are directly connected to the main shaft.

Six combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air for braking is supplied by the station compressed air system and is automatically controlled. Oil pressure for jacking the rotor is applied by means of a portable hand-operated oil pump when required.

A carbon dioxide fire-extinguishing system is provided with nozzles located in ring headers above the rotor.

A sectional elevation of the generator is shown in figure 78, and a view of the generator room is shown in figure 79.

Oil systems

The governor and lubricating oil purification system consists of one 350-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 2,500-gallon capacity; and the necessary connecting piping for the supply and return of oil to the governor and to the generator and turbine bearings. The turbine bearing oil-circulating system includes an alternating-current pump and a direct-current pump for standby use. The purifier, pumps, and storage tanks are in the basement of the powerhouse.

Also in the basement of the powerhouse are the pumps and purification equipment of the insulating oil system. One clean- and one dirty-oil pump, each of 100-gallon-per-minute capacity, and an insulating oil purifier with a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press are located in the oil purification room. Three 7,000-gallon-capacity insulating oil storage tanks (1 for dirty transformer oil, 1 for dirty circuit breaker oil, and 1 for clean oil) are embedded in the fill outside the powerhouse. A complete piping system is furnished for filling and draining

FIGURE 79.—*Ocoee No. 3 generator room.*

the electrical equipment in the switchyard with conveniently located valve boxes for fill and drain hose connections.

Compressed air system

An air-cooled compressor, rated at 8 cubic feet per minute and 300-pound-per-square-inch pressure, which was purchased for the governor is utilized to furnish normal station compressed air requirements and generator brake service, in addition to governor air. The compressor is direct-connected to the 84-cubic-foot station air receiver and to the governor pressure tank. Air pressure at 100 pounds per square inch is automatically maintained in the station air receiver by a pressure governor. Air supply to the 300-pound-per-square-inch governor pressure tank is manually controlled.

Two separate 100-pound-per-square-inch air systems are connected to the receiver, one supplying the generator brakes and the other supplying the remaining station air services, consisting of the grease compressor, treated water hydropneumatic tank, and 1-inch service outlets. Provision is made to isolate the receiver and generator brake air system from the powerhouse air system during periods of construction or repair work when the demand for compressed air is greater than the capacity of the stationary air compressor. A portable, air-cooled, motor-driven air compressor having a capacity of 105 cubic feet per minute at 100 pounds per square inch is available for general service and may be connected into the powerhouse air system through a service outlet in the machine shop.

Raw water system

An intake in the penstock supplies normal raw water requirements for fire protection, cooling, and various other services. After passing through a multiple-basket rotary strainer the supply branches into three systems. One supply header at unreduced pressure (195 pounds per square inch maximum) furnishes water to the station drainage eductor. A second system is reduced to 80-pound-per-square-inch pressure for the station service, lawn sprinklers, and powerhouse and switchyard fire protection. Three fire hydrants are in the switchyard. A 200-gallon-per-minute emergency fire and service pump in the powerhouse basement provides an alternate source for this system. The pump has an intake from tailwater and is intended for use when the penstock butterfly valve is closed and the normal supply is shut off.

The third system is reduced to 40-pound-per-square-inch pressure and supplies the turbine and generator cooling water requirements. This system furnishes water to the generator air and bearing oil coolers and to the turbine stuffing box and runner seals. The supply to the generator air coolers is controlled by a motor-operated proportioning valve with controller, and by a thermometer bulb mounted in the generator air housing. A motor-operated gate valve provides remote control for operation of this system.

The raw water supply for unit cooling and lubrication has a series of alarm circuits operated by flowmeters to indicate low flow The flowmeters in the generator bearing oil cooler and turbine supply lines have an additional contact to shut down or prevent starting the unit on low flow.

Treated water system

Although the unit is designed for remote control under normal operating conditions, a filter plant was installed for the use of maintenance employees. The raw water intake is located in the bed of Little Gassoway Creek near the powerhouse, from which the water flows by gravity to the filter plant in the basement of the powerhouse. The plant is equipped with a strainer, a 10-gallon-per-minute supply pump, a closed, baffled mixing tank, two pressure filters, chemical feeders, hypochlorinators, and a pneumatic storage tank which has a working capacity of 465 gallons. The system supplies the powerhouse sanitary fixtures at a minimum pressure of 25 pounds per square inch.

A treated water distribution and storage system in the dam to be supplied from the powerhouse by a tank truck serves the sanitary fixtures. A 10-gallon-per-minute motor-driven pump located in the building near the parking area delivers water to the 230-gallon storage tank in the operator's room.

Sewage disposal

The waste from the toilet facilities in the powerhouse drains into a 450-gallon steel septic tank located in the powerhouse at elevation 1130. Under normal conditions of tailwater, the effluent from the septic tank drains directly into the tailrace by gravity through an outlet in the downstream face of the powerhouse substructure at elevation 1107. When tailwater rises about elevation 1130, the effluent is diverted to the station sump from where it will be auto-

matically discharged to tailwater through the station drainage system.

Waste from the sanitary fixtures located in the operator's room in the dam drains into a concrete septic tank under the stairwell entrance to the room. The effluent from the septic tank joins with building drainage water and is carried to the stream bed near the spillway apron training wall.

Drainage and unwatering

The station drainage and unwatering sump is located in the basement of the service bay. Powerhouse drainage below high tailwater is carried to the sump. All roof drainage is carried directly to tailwater.

The station sump has an approximate capacity of 10,000 gallons and is serviced by a 6-inch water jet eductor and a 335-gallon-per-minute, deepwell, turbine-type pump. The discharge water is carried directly to tailwater. The pump acts as a standby should the eductor fail to handle the drainage. The pump is also used for station drainage when the penstock butterfly valve is closed as high pressure would not be available for operation of the eductor.

With tailwater elevation about normal, or below, the runner may be inspected through the draft tube access door by closing the penstock butterfly valve and draining the unit to tailwater, leaving the draft tube gates in open position. The wicket gates may be closed and inspected in a similar manner for leakage except the butterfly valve need not be closed or the penstock drained. Complete unwatering of a draft tube is considered an extremely infrequent operation, not warranting the installation of high-capacity, permanent pumping facilities for that purpose.

The station drainage emergency sump pump may be used for draft tube unwatering by draining the draft tube to the sump and pumping the water to the tailrace.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is provided for the generator, the oil storage room, and the oil purification room. The system consists of two banks of 50-pound cylinders, a combination initial and reserve bank of fourteen cylinders, and a delayed bank of six cylinders. Seven cylinders of the combination bank are arranged for simultaneous discharge to the generator, and the remaining seven cylinders are arranged with interconnecting piping and controls to function as reserve protection for the generator. The delayed discharge bank is arranged for intermittent release to maintain a sufficient concentration of carbon dioxide in the generator housing. Normally, the seven reserve cylinders are used for proection of the oil storage room and the oil purification room.

Portable carbon-dioxide fire-extinguishing units are conveniently located in the powerhouse, valve house, and switchyard. One 100-pound wheel-type unit is stationed in the switchyard.

A supply of raw water at a reduced pressure of 80 pounds per square inch from the penstock is used for general fire protection in the powerhouse and switchyard. Three fire hose racks with 75 feet of fire hose are located in the powerhouse, and three 4-inch fire hydrants and a fire equipment building containing a fire hose cart

assembly are located in the switchyard. A 200-gallon-per-minute emergency fire pump in the basement of the powerhouse with an intake from the tailrace is provided for use when the penstock is unwatered.

Service equipment

The machine shop, located in a room adjacent to the erection area of the powerhouse generator room, is equipped with only the smaller machines required for routine maintenance as listed in table 14, page 626. Any repair work requiring the use of larger machine equipment can be handled by the machine shop at Hiwassee project.

An emergency source of power for operation of the spillway gates and dam lighting is supplied by a gas-electric generator set which is installed in a room adjacent to the operator's room in the dam. The generator rating is 35 kilovolt-amperes, 0.8 power factor, 480 volts, 3 phase, and 60 cycles. The 6-cylinder, air-cooled gasoline engine rating is 71 brake-horsepower at 1,200 revolutions per minute. A view of this emergency power unit is shown in figure 80.

Heating and ventilating

The powerhouse and the gas-electric generator and operator's rooms located in the dam are mechanically ventilated. Electric unit heaters throughout these spaces and the value house heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Heated air exhausted from the powerhouse electric equipment rooms may be recirculated during cold weather to conserve heat. Portable electric heaters supplement the permanently connected heaters as required.

The valve house is provided with dampers which are designed to automatically open wide to admit the large quantity of outside air required during penstock and unit unwatering, when pressure within

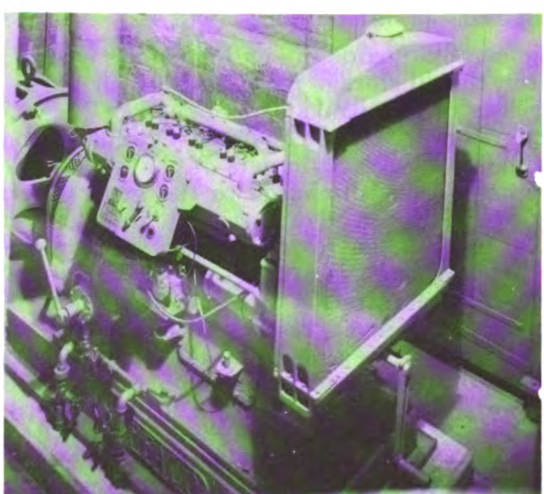


FIGURE 80.—*Ocoee No. 3—35-kilovolt-ampere emergency auxiliary power generator located in dam.*

the building is reduced by exhausting of air through the penstock valve.

A total of 45,850 cubic feet of air (supplied and exhausted) for venilating purposes was provided and 188 kilowatts of electric heating was installed for the complete project.

APALACHIA

The Apalachia project is on the Hiwassee River downstream from Hiwassee Dam and is very similar in function and in layout to Ocoee No. 3 project. The Apalachia Dam is located at river mile 66, downstream 9.8 miles from Hiwassee Dam. The reservoir provides 35,730 acre-feet of controlled storage between normal maximum and minimum pool levels for equalizing peak operations at Hiwassee and for late season drawdown. A storage volume of 8,700 acre-feet is available for pumping operation of Hiwassee Unit 2 pump-turbine. The top of the spillway gates at Apalachia permits a maximum drawdown of 8 feet for pumping.

The Apalachia Dam (fig. 81) is connected to the 2-unit powerhouse (fig. 82) by a 44,000-foot pressure conduit, and develops a maximum gross head of 440 feet. Plans, elevations, and sections are shown in figure 11, page 25. Authorization, construction, operation, and cost data are as follows:

Authorization	July 17, 1941
Construction started	July 17, 1941
Closure	February 14, 1943
Commercial operation:	
Unit 2	September 22, 1943
Unit 1	November 17, 1943
Cost of the 2-unit project, including switchyard	$23,679,582

The Apalachia Dam is a straight, all concrete gravity structure with a crest length of 1,308 feet and a maximum height of about 150 feet. It consists of a 374-foot-long spillway section in the natural river channel and nonoverflow sections extending from the spillway to the abutments at each side. The overfall spillway has ten 23- by 32-foot radial crest gates and is designed for a discharge capacity of 156,600 cubic feet per second. Individual gate hoists are mounted on the bridge across the top of the spillway piers. The intake conduit facilities are located in the nonoverflow section near the left abutment. The intake is protected by trashracks and is controlled by a wheel-type gate operated by a fixed hoist. An operator's room is located at the extreme left end of the dam.

The pressure conduit between dam and powerhouse is on the south side of the river. From the intake at the dam, an 18-foot-diameter welded steel pipe extends about 900 feet downstream to the tunnel portal. Except for a short steel pipe crossing Turtletown Creek and three opencut adits for construction, the tunnel is continuous to the powerhouse penstocks. The tunnel is concrete lined with a finished diameter of 18 feet except for about 6,000 feet in exceptionally good rock. Where required to withstand the hydraulic pressure, welded steel pipe liners 16 or 18 feet in diameter are provided. The differential surge tank is entirely below ground in the ridge adjacent to the powerhouse. The tank is 66 feet in diameter, concrete lined, with a 16-foot-diameter steel riser.

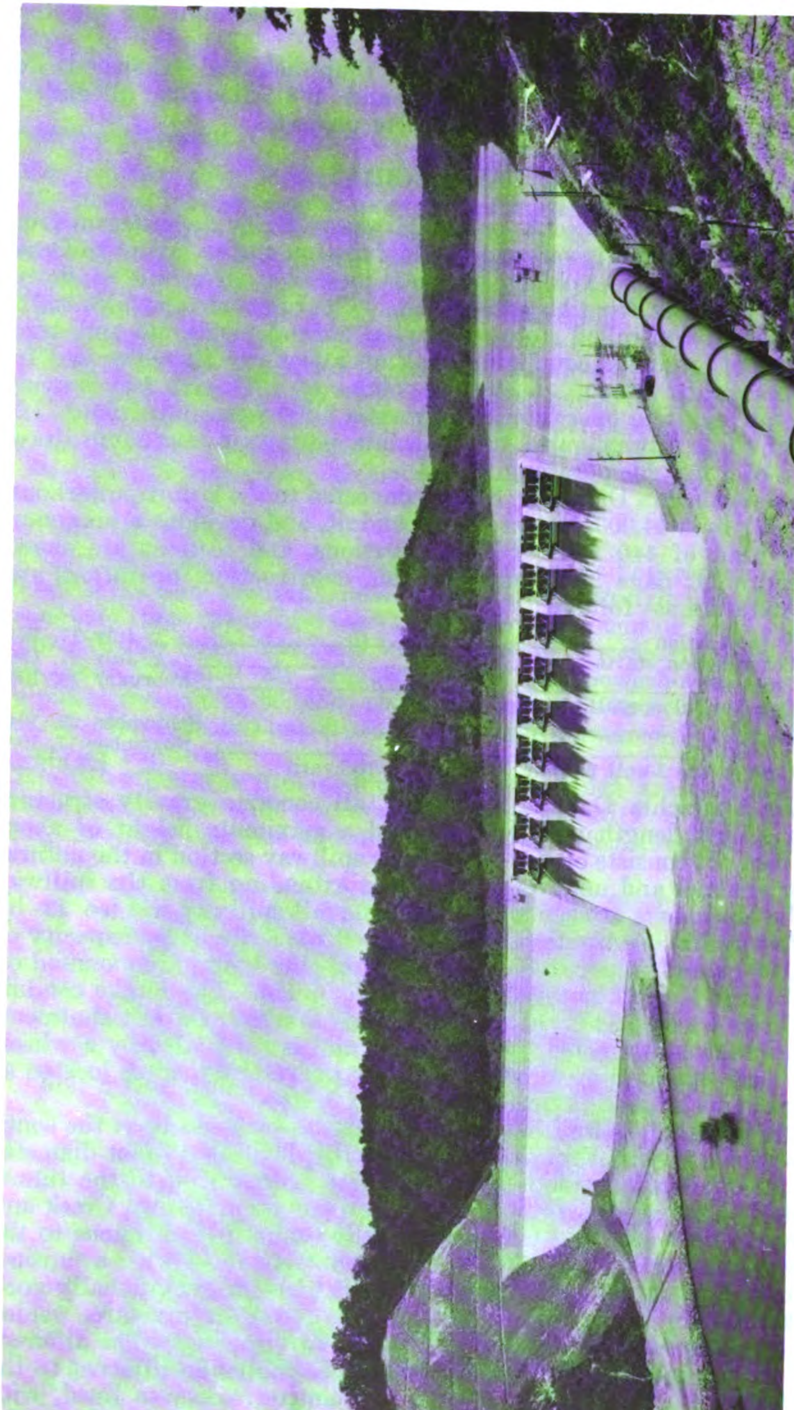


FIGURE 81.—*Apalachia Dam 12.5 miles upstream from powerhouse.*

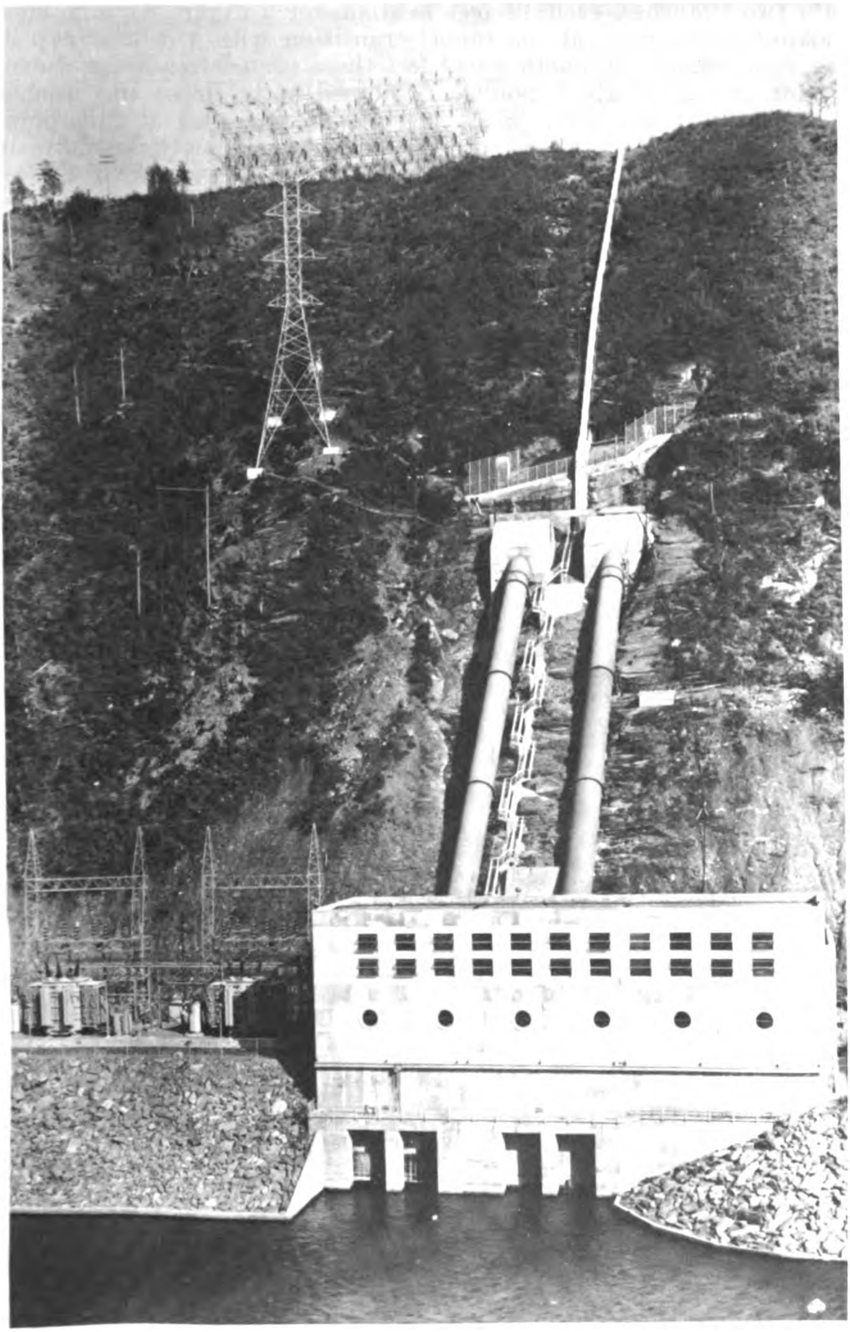


Figure 82.—*Apalachia powerhouse, penstocks, and switchyard.*

About 100 feet downstream from the surge tank the tunnel divides into two branches, each 12 feet in diameter. Figure 83 is a view looking downstream at the tunnel transition with a debris trap in the foreground. In another 250 feet these tunnels reach the downstream portal at which point a combined valve house and anchor block is built (fig. 84). Each conduit is controlled at this point by a butterfly valve 12 feet in diameter. Immediately downstream from these valves the steel penstocks reduce to a diameter of 11 feet and turn down the hill. At the foot of the hill the penstocks pass below the track of the Louisville and Nashville Railroad and connect to the scroll cases of the turbines in the powerhouse. A view of the powerhouse and penstocks is shown in figure 82.

The indoor-type powerhouse is on the river side of the railroad. The powerhouse substructure is approximately 147 feet long and about 87 feet wide, consisting of two unit blocks and a service bay. The superstructure encloses the generator room, a crane support, and a 4-story equipment bay. A section through the powerhouse is shown in figure 85.

The main transformers are located on fill just upstream from the powerhouse. The switchyard is located on top of the ridge adjacent to the surge tank area.

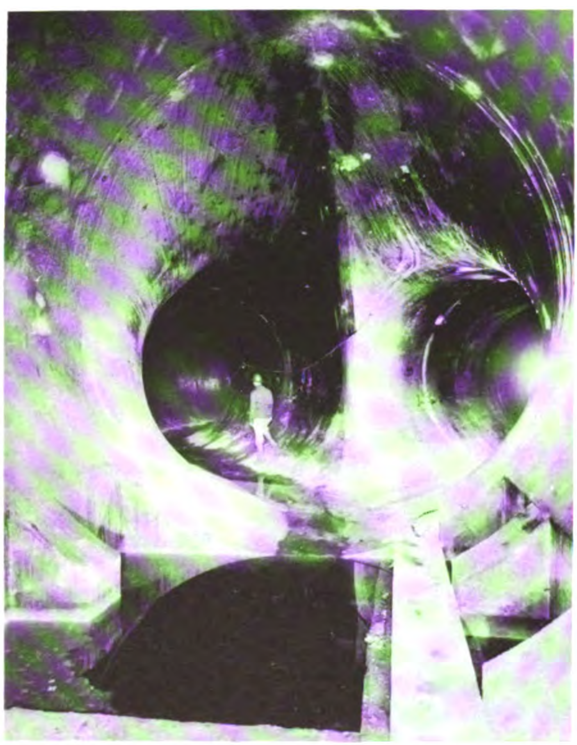


FIGURE 83.—*Apalachia 18-foot-diameter tunnel transition to two 12-foot-diameter tunnels—debris trap in foreground.*

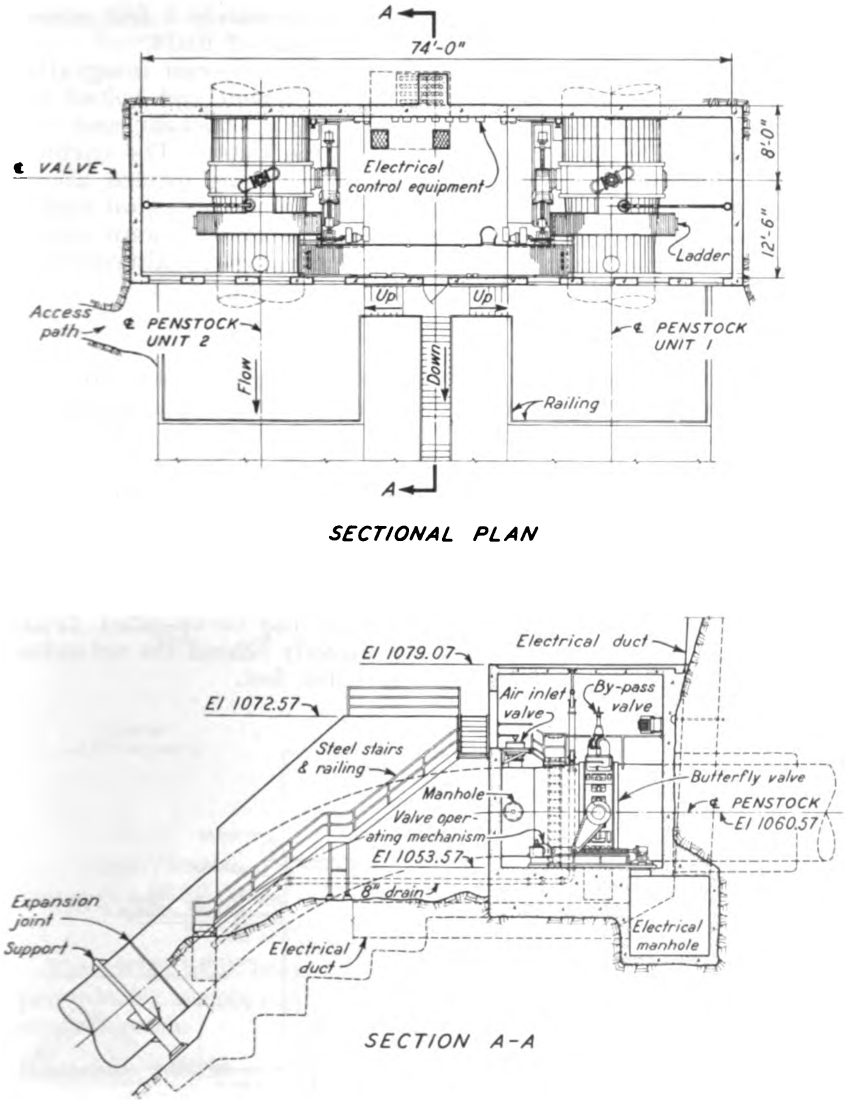


Figure 84.—*Apalachia butterfly valve house with two 12-foot-diameter valves.*

Turbines

Two vertical Francis hydraulic turbines manufactured by the Baldwin-Lima-Hamilton Corp. are direct-connected to the 40,000-kilovolt-ampere synchronous generator (fig. 86). The turbines are each rated 53,000 horsepower at 360-foot net head and operate at a speed of 225 revolutions per minute. They are designed to operate satisfactorily under any head from a minimum of 330 feet to a maximum of 420 feet and are most efficient at a net head of about 390 feet. Each has a maximum runaway speed of 440 revolutions per minute. At rated conditions the value of specific speed is 33,

and the center line of the runner is set approximately 6 feet above normal tailwater elevation giving a plant sigma of 0.073.

The spiral case and stay ring for these units were cast integrally. They were sectionalized for handling and shipment and bolted together in the field. The cast-steel runner has 15 buckets, and the water to the runner is controlled by 20 wicket gates. The turbine shaft is guided by an oil-lubricated, babbitt bearing located above the head cover. An alternating-current oil pump supplies oil under normal conditions to the bearing, and a direct-current pump comes into operation automatically in case of failure of the alternating-current pump to supply sufficient oil to the bearing.

Governors

A single cabinet-actuator type governor manufactured by the Woodward Governor Co. is provided for each unit. The governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for control of the turbine from the actuator. Since the actuators are in the control room, turbine operators are not required.

The oil pumps are the herringbone-gear type with a capacity of 100 gallons per minute at 300 pounds per square inch and are driven by 30 horsepower motors. The two governors have interconnected oil pressure systems so that both governors may be operated from one oil pump. The pressure tanks are directly behind the actuator cabinets, and each has a volume of 91 cubic feet.

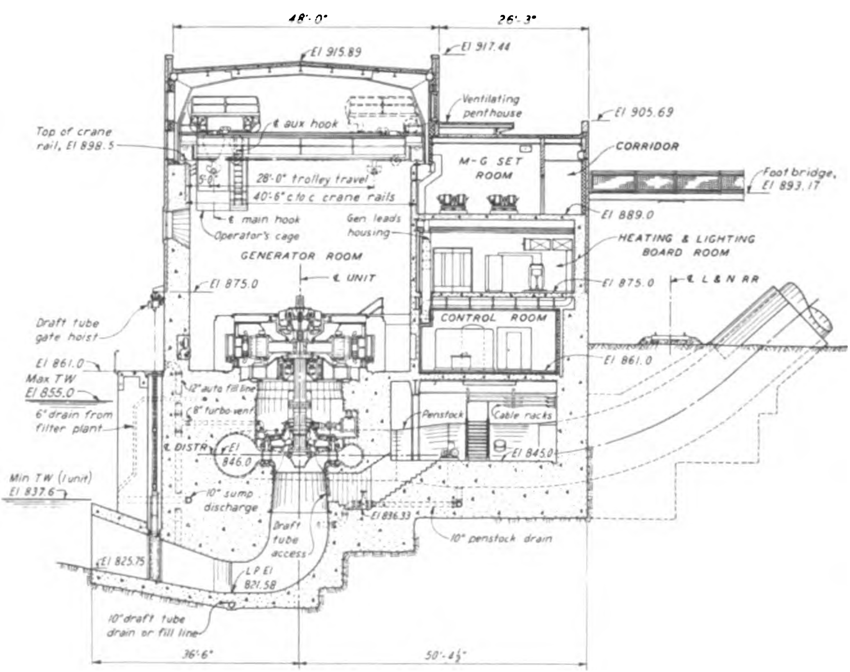
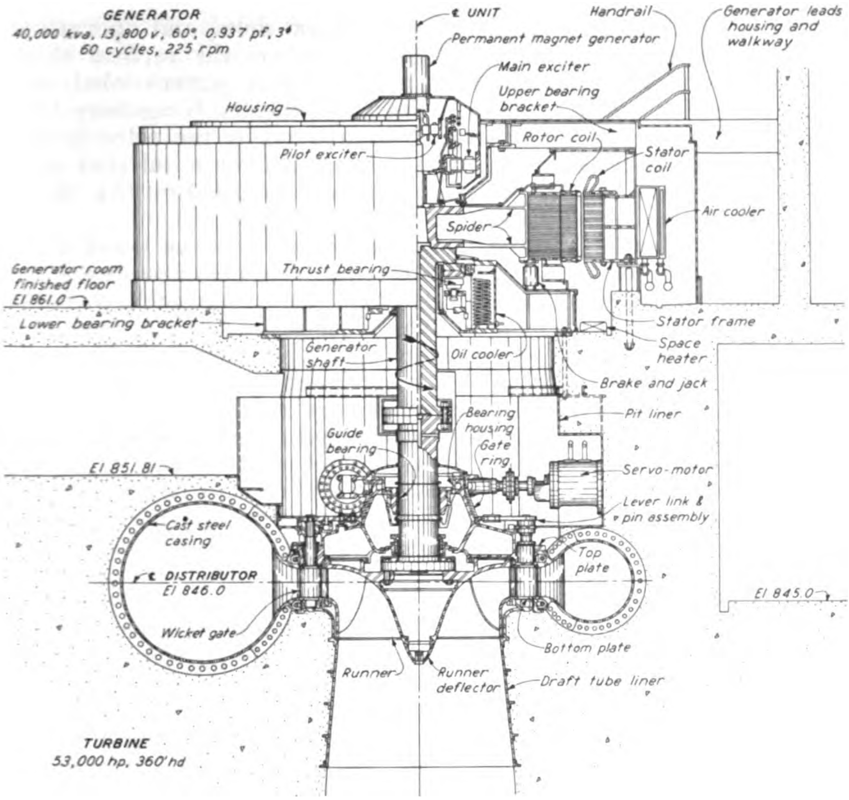


FIGURE 85.—*Apalachia powerhouse cross section.*



LONGITUDINAL SECTION
LOOKING UPSTREAM

TRANSVERSE SECTION
UPSTREAM SIDE

FIGURE 86.—*Apalachia turbine and generator sections.*

Estimates have been made for future installation of facilities to provide for remote control of the Apalachia units from the Hiwassee control room.

Butterfly valves

One 144-inch butterfly valve is located in each penstock about 300 feet upstream from the powerhouse. Each valve is bypassed by a 12-inch valve for filling the spiral case and penstock after an unwatering operation. Each butterfly valve is equipped with a 20-horsepower motor and is set for a closing time of 300 seconds. The clear opening through the valve with the gate wide open is 75 percent of the valve area, and the leakage with the valve closed under 222-foot head is guaranteed not to exceed 300 gallons per minute. The valve is equipped with a device which will automatically close the valve gate in case of excessive flow.

Generators

The two generators, manufactured by the Westinghouse Electric Corp., each have a rated capacity of 40,000 kilovolt-amperes or

37,500 kilowatts at 0.937 power factor, 13,800 volts, and operate at 225 revolutions per minute. The generators are the vertical shaft type and are totally enclosed and air cooled with water-cooled heat exchangers within the housing. The combination Kingsbury-type thrust and segmental guide bearing located below the rotor is immersed in an oil reservoir which is maintained at a suitable temperature by water coolers. The exciters are mounted on the upper bracket and are direct-connected to the main shaft.

Six combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air at 100-pound-per-square-inch pressure for braking is supplied by the station compressed air system and is controlled manually at the actuator. Oil pressure at 1,700 pounds per square inch for jacking the rotor is applied by means of a portable hand-operated oil pump when required.

A carbon-dioxide fire extinguishing system is provided with nozzles located in ring headers above the rotor.

A sectional elevation of the generator is shown in figure 86, and a view of the generator room with unit 1 in the foreground is shown in figure 87.

Oil systems

The governor and lubricating oil purification system consists of one 350-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 3,000-gallon capacity; and the necessary connecting piping for the supply and return of oil to the governor and to the generator and turbine bearings. The turbine bearing oil-circulating system includes an alternating-current pump with a direct-current pump for standby service. The purifier, pumps, and storage tanks are in the basement of the service bay.

The insulating oil pumping, purification, and storage equipment for the transformer yard at the powerhouse is also in the basement of the service bay. The oil storage facilities consist of two 6,025-gallon tanks for dirty transformer oil and one 6,025-gallon tank for clean transformer oil. One clean-oil pump of 100-gallon-per-minute capacity fills the electrical equipment with clean oil. The transformer yard electrical equipment is drained by gravity through hose

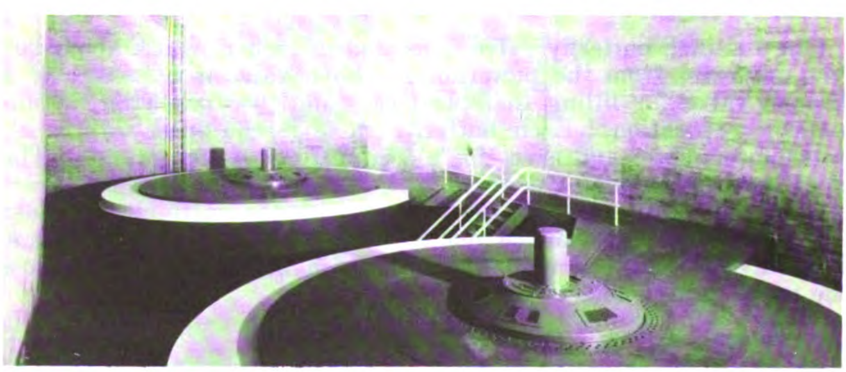


FIGURE 87.—*Apalachia generator room.*

connections to the drain header and thence to the dirty-oil storage tanks and purifier. The portable purifier with heaters and filter press and having a capacity of 600 gallons per hour is provided with hose connections to the piping system. All connections between the transformer yard equipment and the piping system are made with flexible hose through 2-inch drain and 1½-inch fill connections in the valve boxes.

There are separate insulating oil transfer and storage facilities for the circuit breakers in the switchyard. The system consists of 1 clean- and 1 dirty-oil storage tank, each of 6,500-gallon capacity; one 100-gallon-per-minute outdoor-type oil transfer pump; and a complete piping system with conveniently located valve boxes for hose connections to the equipment. The portable insulating oil purifier which is normally stored in the oil purification room in the powerhouse is to be connected into the piping manifold at the tanks and pump, which are located at the north end of the switchyard.

Compressed air systems

A stationary single-stage, double-acting air compressor with a capacity of 105 cubic feet per minute at 100 pounds per square inch is in the service bay to supply station service and generator air brake requirements. A complete piping system with service outlets throughout the powerhouse is provided. The system includes a 100-cubic-foot air receiver, a water-cooled aftercooler, and control equipment for automatic operation.

A portable air-cooled, motor-driven air compressor of 85-cubic-foot-per-minute capacity at 100-pound-per-square-inch pressure is available for general service.

Compressed air for the governor system is supplied by an 8-cubic-foot-per-minute compressor, complete with piping system, operating at 300-pound-per-square-inch pressure.

Raw water system

A 10-inch raw water manifold with intakes in each unit penstock supplies the station raw water requirements. Two multiple-basket rotary strainers supply three separate branch systems. One branch at unreduced pressure (270 pounds per square inch maximum) supplies water to the station drainage and unwatering eductors. A second branch is reduced to 80 pounds per square inch and supplies the station service and fire protection system, including cooling water supply to the station air compressor and air-conditioning equipment and raw water supply to the filter plant. The third branch is reduced to 40 pounds per square inch by individual unit pressure reducing valves and supplies the requirements of the turbine stuffing box and upper runner seal, the generator air coolers, and the generator bearing oil coolers. All pressure reducing valves are equipped with bypasses, and relief valves are installed in the reduced pressure lines.

An emergency fire pump of 200-gallon-per-minute capacity and an emergency raw water supply pump to the filter plant of 20-gallon-per-minute capacity are installed in the basement of the service bay with a common intake from tailwater for emergency use in event the penstocks were unwatered.

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Indicating flowmeters or flo-sigs are installed in the turbine, generator air, and generator bearing oil cooling water supply lines to each unit with contacts for annunciation indicating low flow.

Treated water system

Treated water for drinking and sanitary use in the powerhouse is supplied from a 20-gallon-per-minute pressure-type filter plant located in the service bay. For a complete description of the Apalachia filter plant refer to chapter 9, "Treated Water Systems."

The treated water is pumped to a 1,000-gallon storage tank in the valve house by one of two 35-gallon-per-minute service pumps which are float-switch-controlled. The powerhouse sanitary system obtains water at a pressure of 80 pounds per square inch from this tank.

The sanitary fixtures in the operator's room at the dam are supplied by gravity flow from a 220-gallon storage tank suspended from the ceiling of the room. The tank is filled from a tank truck by a 20-gallon-per-minute pump located in the inspection gallery and adit through a fill box near the gallery entrance.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into an 800-gallon steel septic tank located at elevation 845. Under normal conditions of tailwater, the effluent from the septic tank drains directly into the tailrace by gravity through a 3-inch pipe, the outlet of which is located in the south embankment at the end of the tailrace retaining wall. When tailwater rises above elevation 845, the effluent is diverted to the station sump from which it will be automatically discharged to tailwater through the station drainage system.

The waste from the toilet fixtures at the dam discharges into a 500-gallon septic tank located in mass concrete below the floor, elevation 1276. The effluent from the tank discharges to the tailrace through a 2-inch cast-iron pipe, terminating at elevation 1177.

Drainage and unwatering

The station drainage and unwatering sump is located in the basement of the service bay. All floor, gutter, wheel pit, and miscellaneous drainage below maximum tailwater elevation flows into this sump, which has an approximate capacity of 10,000 gallons and is serviced by one 6-inch, 300-gallon-per-minute eductor, one 10-inch, 1,000-gallon-per-minute eductor, and a 450-gallon-per-minute, deep-well, turbine-type pump. High-pressure strained water from the unit penstocks provides the operating medium for the eductors. The discharge from the eductors flows directly to tailwater.

Under normal operation the 6-inch eductor pressure supply valve will be opened sufficiently to discharge all station drainage entering the sump. If water in the sump rises to elevation 832, the sump pump will start by float control and stop when the water level drops to elevation 821. A float-controlled alarm will sound on the station annunciator system if the water level reaches elevation 834.

Roof drainage and discharge water from air-conditioning equipment flow directly to tailwater.

The units are normally unwatered by closing the penstock butterfly valve and draining the unit to tailwater with the draft tube gates in the open position. For complete unwatering, each draft tube has a drain outlet connected to the station sump through a floorstand-operated gate valve. After closing the draft tube gates, the unit draft tube drain valve is opened, and the draft tube is unwatered by operation of the 10-inch unwatering eductor. The scroll case is drained through a 10-inch drain line to the draft tube. A 10-inch draft tube fill line with floorstand-operated valves permits the draft tube to be filled to tailwater elevation prior to opening the draft tube gates following an unwatering operation of either unit. An automatic draft tube fill line prevents excessive uplift pressures.

Fire protection

A carbon dioxide fire extinguishing system protects the generators, the oil storage room, and the oil purification room. The system is arranged for remote automatic and local manual operation. There are three banks of 50-pound cylinders consisting of an initial bank of 10 cylinders, a delayed bank of 6 cylinders, and a reserve bank of 22 cylinders. The initial bank is arranged for the simultaneous discharge of the 10 cylinders to either generator. The delayed bank is arranged for intermittent release. Eleven cylinders of the reserve bank are arranged with interconnecting piping and controls to function the same as the initial bank for generator protection. The remaining 11 cylinders are used for protection of the oil purification room. All 22 cylinders of the reserve bank are used for the protection of the oil storage room.

Portable carbon-dioxide fire-extinguishing units are conveniently located in the powerhouse, the valve house, the transformer yard, and the switchyard. One 100-pound wheeled unit is in the transformer yard, and an additional one is in the switchyard.

Raw water is supplied at a reduced pressure of 80 pounds per square inch from the unit penstocks for general fire protection in the powerhouse and transformer yard. The powerhouse fire protection equipment includes four fire hose racks, each equipped with a valve, 75 feet of fire hose, and a nozzle. The transformer yard equipment includes two 4-inch fire hydrants and a portable fire hose cart with 100 feet of fire hose and atomizing hose nozzles. An emergency fire pump with a capacity of 200 gallons per minute is in the basement of the service bay and connected to the system. The pump, which has an intake from tailwater, is intended for use in case the penstocks are unwatered.

An estimate has been prepared for the future installation of an automatic fire protection system of the water fog type for the transformer yard. The proposed system is described in chapter 13, "Fire Protection."

Service equipment

The machine shop, located in a room adjacent to the erection bay, is equipped with only the smaller machines required for routine maintenance of the power plant equipment. The machine shop equipment is listed in table 14, page 626. Any repair work requiring

the use of larger machine equipment is intended to be serviced by the machine shop at Hiwassee project.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, telephone room, and offices. The remainder of the powerhouse, the operator's room in the dam, and the valve houses are mechanically ventilated. Electric unit heaters located throughout the buildings heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Heated air exhausted from the electrical equipment rooms may be recirculated to the powerhouse during cold weather to conserve heat. Portable electric heaters supplement the permanently connected heaters.

The air-conditioned spaces are served by combination heating, cooling, and ventilating systems complete with fan, electric blast heater, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by circulating lake water through the cooling coils.

The valve house is provided with dampers which are designed to automatically open to admit the large quantity of outside air required during penstock and unit unwatering, when the penstock air valve opens to admit air.

The design requirements of these systems are as follows:

Cubic feet per minute of air supplied and exhausted	59,000
Kilowatts of installed electric heating	302

FORT LOUDOUN

Fort Loudoun Dam is the last of seven main-river dams constructed by TVA to complete the 9-foot navigation channel from the mouth of the Tennessee River to Knoxville. The project extends the channel a distance of 45.4 miles from the headwater of Watts Bar Reservoir, provides 109,300 acre-feet of controlled storage for flood control, and adds a generating capacity of 128,000 kilowatts to the system. Although not originally intended as an emergency project, with the advent of World War II the original construction program was accelerated as a national defense measure.

Fort Loudoun Dam is on the Tennessee River at river mile 602.3, upstream 72.4 miles from Watts Bar Dam, and 1 mile upstream from the mouth of the Little Tennessee River. The project is named for the fortification of that name which was erected and garrisoned by the colony of South Carolina (1756–60) and located about 14 miles from the dam site on a narrow ridge in the fork of the Little Tennessee and Tellico Rivers.

Authorization, construction, operation, and cost data are as follows:

Authorization:	
Project and units 1 and 2	July 3, 1940
Units 3 and 4	January 15, 1942
Construction started	July 8, 1940
Closure	August 2, 1943
Commercial Operation:	
Unit 2	November 9, 1943
Unit 1	January 15, 1944
Unit 3	October 17, 1948
Unit 4	January 27, 1949
Cost of 4-unit project including switchyard	$42,967,403

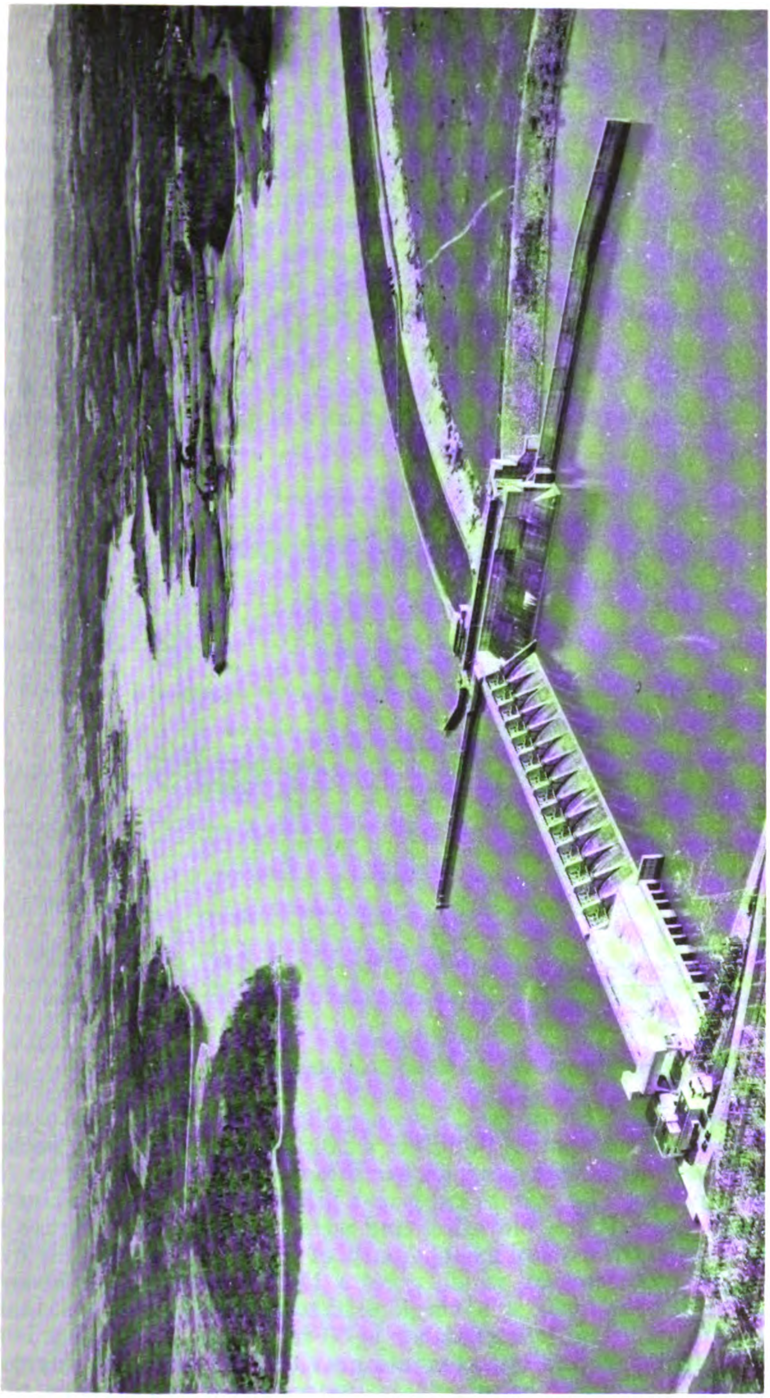


FIGURE 88.—*Fort Loudoun project.*

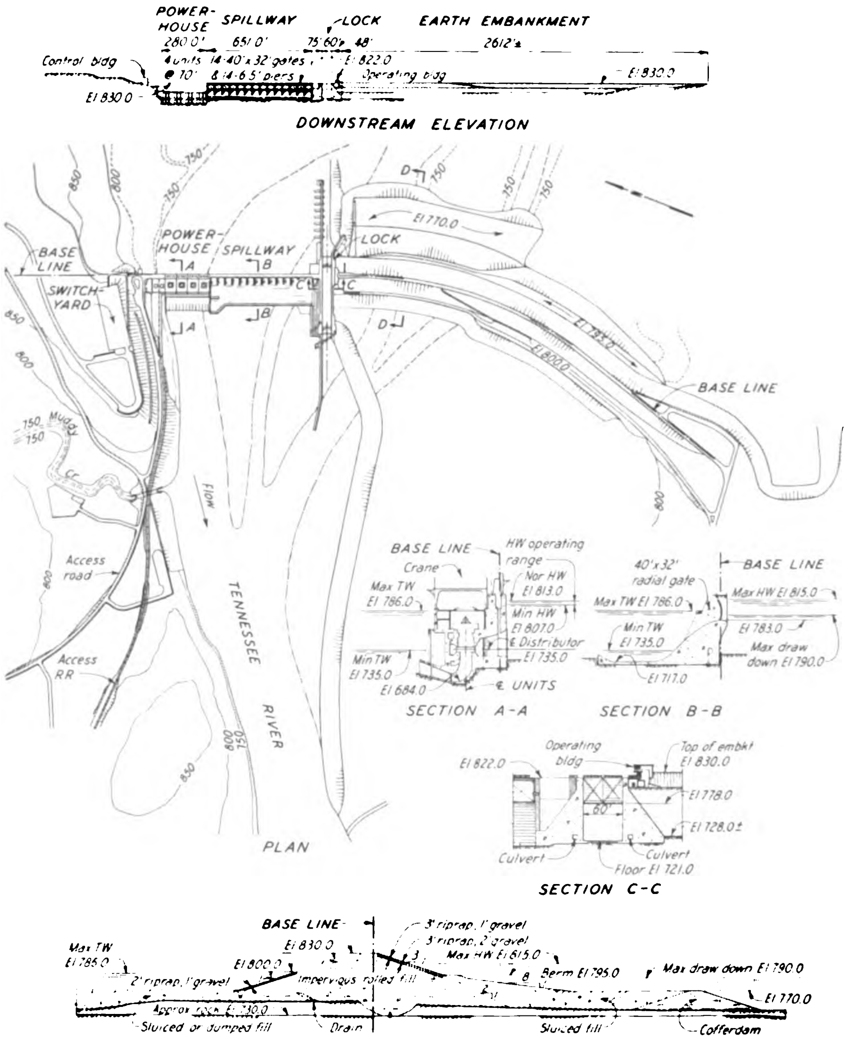


FIGURE 89.—*Fort Loudoun—plan, elevation, and sections.*

The Fort Loudoun project, shown in figure 88, consists of a non-overflow section, a control building, a powerhouse, a spillway section of the ogee type, a lock, and an earth embankment which is on the left flood plain. The switchyard is on a hill north of the control building. The general plan, elevation, and sections are shown in figure 89.

The main earth embankment is built of impervious rolled fill with the top at elevation 830, which gives a 15-foot minimum freeboard.

The navigation lock is a single lift structure with a maximum lift of 80 feet. The lock chamber is 60 feet wide by 360 feet long.

The spillway section is a concrete gravity structure with fourteen 40- by 32-foot radial gates and is designed for the passage of a maximum flood of 390,000 cubic feet per second. The spillway extends between the lock and powerhouse.

The powerhouse intake, which is between the spillway dam and the service bay, contains water intake passages for four hydraulic turbines spaced 70 feet on centers. The intake gates, stoplogs, and trashracks are handled by a 50-ton gantry crane.

The powerhouse contains 4 generating units, 2 of which were initially installed and the other 2 were installed later after being deferred by the War Production Board during World War II. The powerhouse is a reinforced concrete structure of the semioutdoor type with a 225-ton gantry crane mounted on the roof. Equipment is handled by the crane through hatches over the units and the service bay. The crane also operates the draft tube gates. Sections through the powerhouse and service bay are shown in figures 90 and 91.

The service bay is a reinforced concrete structure and serves as a bulkhead dam and as an unloading deck which is serviced by the powerhouse crane. It is a continuation of the intake structure and

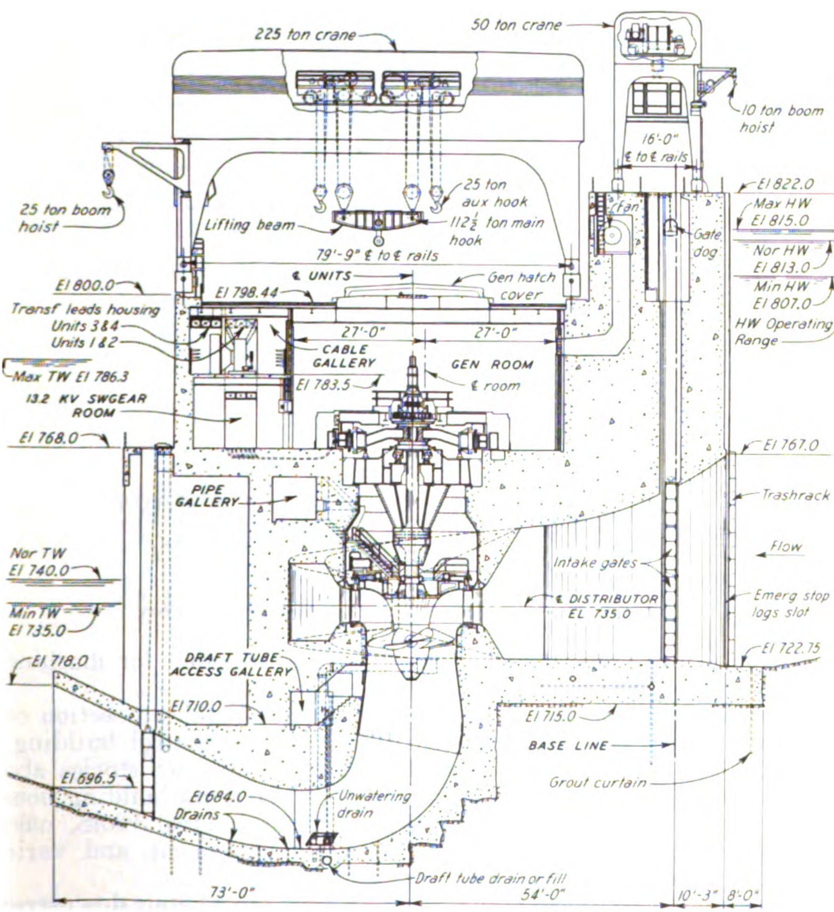


Figure 90.—*Fort Loudoun—section through powerhouse.*

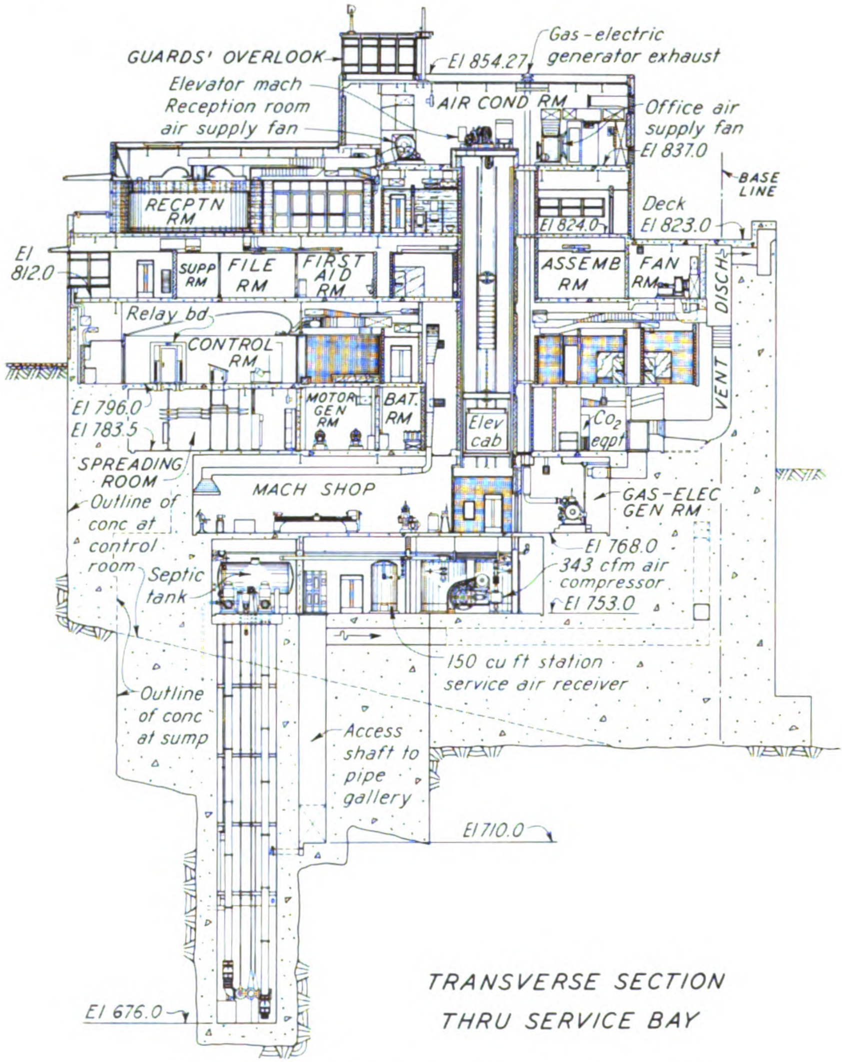


FIGURE 91.—*Fort Loudoun—section through service bay.*

extends to the nonoverflow dam. Space is provided for machinery erection, auxiliary equipment, shops, and storage.

The nonoverflow dam is a concrete gravity bulkhead section connecting the service bay and the hillside. The control building is on the land side of the service bay and extends two stories above the upper deck level of the service bay. The control building houses the machine shop, the spreading room, the control room, offices, facilities for visitors, the air-conditioning equipment, and various auxiliary mechanical and electrical equipment.

The transformer yard is on a concrete deck immediately downstream from the control building and parallel to the river. The switchyard is located on the hill north of the powerhouse.

Turbines

Four Kaplan-type hydraulic turbines manufactured by the Baldwin-Lima-Hamilton Corp. are direct-connected to the generators (fig. 92). The turbines are rated 44,000 horsepower at a net head of 65 feet and operate at a speed of 105.8 revolutions per minute. They are designed to operate under any head from a minimum of 40 feet to a maximum of 70 feet and to withstand a maximum runaway

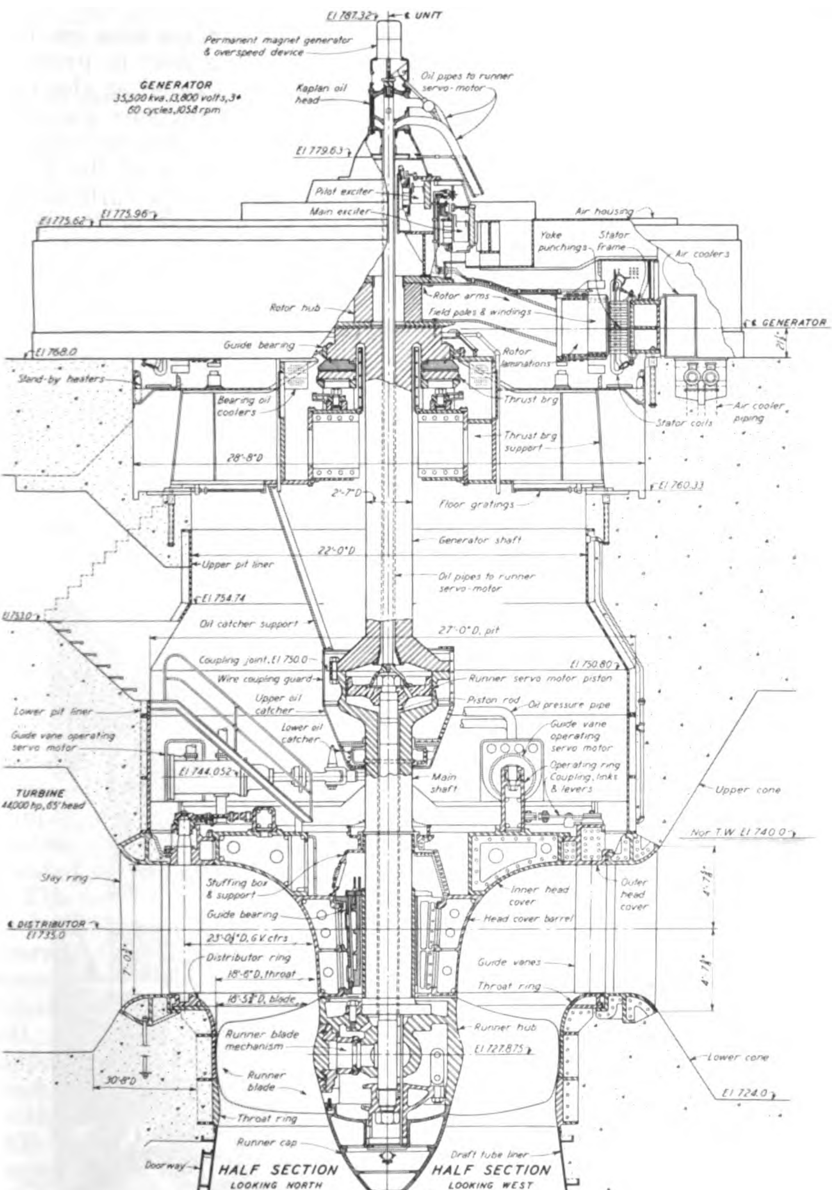


Figure 92.—***Fort Loudoun—turbine and generator sections.***

speed of 282 revolutions per minute. At rated conditions the value of specific speed is 120, and the center line of the runner is approximately 14 feet below normal tailwater elevation giving a plant sigma of 0.69.

The Fort Loudoun units have concrete spiral cases and cast-steel stay rings. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners each have five cast-steel blades set in a cast-steel hub which contains the blade-operating mechanism. Approximately 13 square feet of surface area on the back side of each blade is prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is guided by a water-lubricated bearing of molded plastic material or Insurok located in the bore of the head cover barrel. Transverse and longitudinal sections of the turbine are shown in figure 92 and the assembly of the runner hub is shown in figure 93.

Field erection specifications for these turbines are included in appendix A.

Efficiency acceptance tests were made at the manufacturers' hydraulic laboratory on a homologous model. These tests indicated that the prototype would exceed the efficiency guarantees by an average of more than 4 percent and would meet or exceed the capacity guarantees at all heads.

Governors

The governors are the cabinet-actuator type manufactured by the Woodward Governor Company. Two twin actuator cabinets are

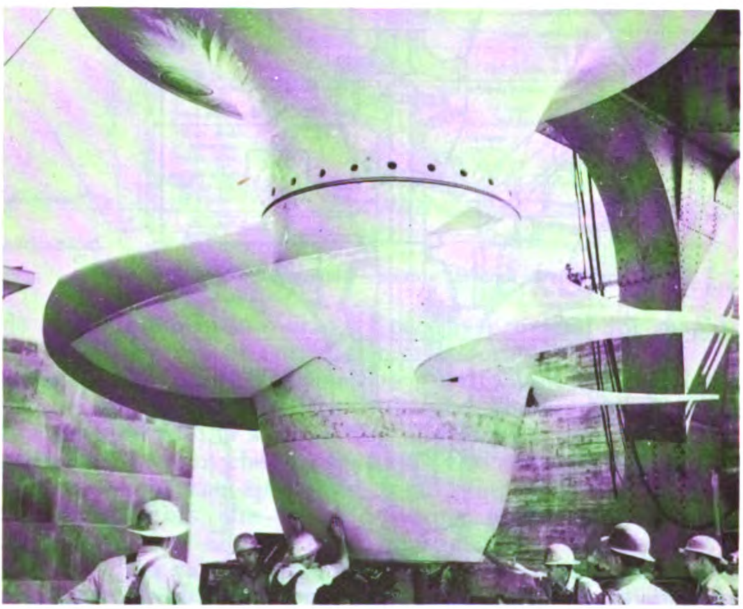


FIGURE 93.—*Assembling Fort Loudon turbine runner hub.*

provided; one for units 1 and 2 and the other for units 3 and 4. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for control of the turbine from the actuator. Each twin cabinet actuator has interconnected oil pressure systems so that both governors may be operated from one oil pump. Each oil pump has a capacity of 270 gallons per minute at 300 pounds per square inch and is driven by a 75-horsepower motor. Each pressure tank has a volume of 346 cubic feet, and each twin sump tank has a volume of 350 cubic feet.

Generators

The four generators, manufactured by the Allis-Chalmers Manufacturing Company, have a normal rating of 35,555 kilovolt-amperes or 32,000 kilowatts at 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and 105.8 revolutions per minute. The main and pilot exciters are mounted above the main rotor. An enclosed water-cooled air-circulating system and carbon-dioxide fire protection are provided. A combination Kingsbury type thrust and segmental guide bearing, located below the generator rotor, is immersed in oil, which is cooled by water coils located in the oil reservoir.

Six combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air for braking is supplied by the station 100-pound-per-square-inch air system and is controlled manually at the actuator. Oil pressure for jacking is applied at 2000 pounds per square inch by a portable hand-operated oil pump connected to the common air and oil header.

A sectional elevation of the generator is shown in figure 92, and a view of the generator room with unit 1 in the foreground is shown in figure 94.

Oil systems

The governor and lubricating oil system consists of one 350-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 4,500-gallon capacity; and the necessary connecting piping for the supply and return of oil to any unit generator bearing or governor system. The lubricating oil purifier, pumps, and storage tanks are located on the elevation 753 floor of the service bay.

The insulating oil pumping, purification, and storage equipment is located on the elevation 796 floor of the service bay. The oil storage facilities consist of two 4,500-gallon-capacity tanks for dirty transformer oil, one 6,400-gallon-capacity tank for dirty circuit breaker oil, and one 6,400-gallon capacity tank for clean insulating oil. These tanks are in the insulating oil storage room. In the adjacent oil purification room are 1 clean-oil and 1 dirty-oil pump, each of 100-gallon-per-minute capacity, and an insulating oil purifier with a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press. A complete piping system supplies and returns oil to the electrical equipment in the switchyard and transformer yard. Connections are made to the equipment with

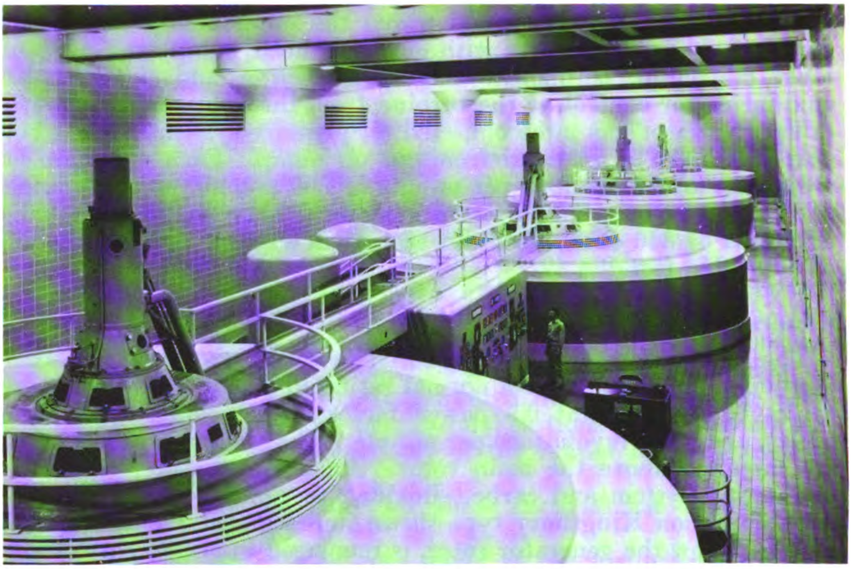


FIGURE 94.—*Fort Loudoun generator room.*

flexible hose through drain and fill valves in conveniently located valve boxes.

A permanent pipe header for filling and draining the runner hub oil is installed in the draft tube access gallery. Each turbine runner hub contains approximately 1,460 gallons of oil which is removed during inspection or dismantling of a unit. Hose connections are provided for the portable pump and storage tanks which were purchased for the Pickwick Landing project and are transported from project to project as required.

Compressed air systems

A complete piping system, with service outlets, distributes compressed air throughout the powerhouse, to the generator brakes, and to the intake and draft tube decks. A stationary, single-stage, double-acting, motor-driven air compressor with a capacity of 113 cubic feet per minute at 100-pound-per-square-inch pressure is located in the basement of the service bay. The system includes a water-cooled aftercooler, a 150-cubic-foot air receiver, and control equipment for automatic operation. A cross connection with a normally closed gate valve permits the draft tube evacuation system to serve as a standby for the station air system.

A draft tube evacuation air system depresses the water level in the draft tubes for operation of the units as synchronous condensers. The compressor is a stationary, single-stage, double-acting, motor-driven unit with a capacity of 343 cubic feet per minute at 100-pound-per-square-inch pressure. Four air receivers provide 2,000 cubic feet of storage capacity. The compressor and receivers are in the basement of the service bay. The system includes a water-cooled aftercooler and control equipment for remote manual operation from the actuator cabinet.

A portable air-cooled, motor-driven air compressor with a capacity of 93 cubic feet per minute at 100-pound-per-square-inch pressure is available for general service.

The governor compressed air system is supplied by an 8-cubic-foot-per-minute compressor with a discharge pressure of 300 pounds per square inch with complete piping system.

Raw water system

Each unit has a normally isolated raw water system with an intake in the scroll case. Two branch lines are supplied from the intake, one flowing by gravity through a twin strainer to the generator air and the generator bearing oil coolers, and the other flowing by gravity through a smaller twin strainer to the turbine bearing, unwatering eductor, and stuffing box.

An emergency raw water supply header with an intake in the forebay at elevation 758 and separate twin strainer is provided with connections to any unit system. Cooling water for the station and draft tube evacuation air compressors and aftercoolers is also supplied from this intake.

Another intake in the forebay at elevation 785.5 supplies cooling water by gravity flow through a twin strainer to the gas-electric generator and the air-conditioning equipment condenser. The gas-electric generator has its own cooling water pump mounted on the machine, and a pump supplies the air-conditioning equipment condenser during periods of low headwater.

Indicating flowmeters or flo-sigs are installed in the turbine, generator air, and generator bearing oil cooling water supply lines to each unit and in the gas-electric generator water supply line with contacts for annunciation indicating low flow. An additional contact in the turbine bearing flo-sig shuts down or prevents starting the unit on low flow.

Treated water system

Treated water is obtained from the Lenoir City system and is used for fire protection in the switchyard, transformer yard, and powerhouse, for all sanitary service, for air-conditioning equipment, for drinking fountains, and for lawn sprinkling. A storage tank of 1,910-gallon capacity on the elevation 837 floor in the service bay supplies water for short emergency shutoff periods when required. A 4-inch header extends through the spillway drainage gallery to the lock operations building and the left embankment.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 2,700-gallon metal septic tank located in the service bay at elevation 753. Under normal conditions of tailwater, the effluent from the tank drains directly into the tailrace by gravity through an outlet in unit 1 draft tube pier at elevation 732. When tailwater rises above elevation 753, the effluent is diverted to the station sump from which it will be automatically discharged to tailwater by the drainage pumps. The waste from the toilet fixtures located on the generator room floor at unit 4 drains directly into the tailrace by gravity through an outlet at elevation 733 in the unit 4 draft tube

pier. During high tailwater a valve in the waste line is closed to prevent water from backing up into the fixtures, the use of the facilities being discontinued.

The waste from the toilet facilities in the lock operation building discharges into a 1,200-gallon steel septic tank in the basement of the building. The effluent from the tank discharges through a 6-inch pipe terminating on the downstream end of the lock wall at elevation 730.

The waste from the toilet facilities in the public toilet building in the picnic and marina area discharges into a 2,000-gallon septic tank approximately 90 feet south of the building. The effluent from the tank discharges into a subsurface tile field.

The waste from the toilet facilities in the maintenance building and the machine shop discharges into a 1,000-gallon concrete septic tank located approximately 100 feet south of the maintenance building. The effluent from the tank discharges through a 6-inch line terminating in a creek at elevation 740.

Drainage and unwatering

Powerhouse and service bay dranage from elevation 796 and below is discharged into the station drainage and unwatering sump which is located in the basement of the service bay. The sump has a maximum capacity of approximately 31,300 gallons and is serviced for normal station drainage by two 340-gallon-per-minute, float-operated turbine-type pumps which discharge to tailwater.

Powerhouse roof and service bay deck drainage flows directly to tailwater. Most of the drainage and equipment water discharges above elevation 812 are drained to headwater.

The turbine pit at each unit is unwatered by a 1-inch eductor discharging into the wheel pit drainage system, which flows to the station sump.

Drainage from the spillway gallery is normally carried to the station sump through a 12-inch drain line. If an excess amount of leakage accumulates in the gallery during high water periods it may be necessary to allow the gallery to fill up to tailwater level by closing the valve in the 12-inch equalization line. A check valve and an operating valve were provided in the spillway gallery. The operating valve is normally open to allow excess leakage to equalize to tailwater, thus preventing any buildup of pressure or uplift on the spillway structure greater than that produced by tailwater. This system also prevents exceeding the pumping capacity of the station drainage sump, a condition which might result in flooding portions of the powerhouse.

An unwatering system for all draft tubes and scroll cases was provided to permit inspection and repair of turbine runners, which are below the normal tailwater elevation. Each scroll case has a drain outlet and a 16-inch drain line to the draft tube with shutoff valve. Water in a scroll case drains to tailwater level through the wicket gates and through the 16-inch drain line emptying into its draft tube. Each draft tube has a drain outlet 2 feet above the low point. A 16-inch pipe, with control valve, connects the draft tube drain to an 18-inch header which discharges through its own control valve into the station sump.

Unwatering valves are operated from the unwatering gallery. Two 5,000-gallon-per-minute, deepwell, turbine-type pumps in the station sump handle the draft tube unwatering operation. Either pump may be used to augment the station drainage system.

Fire protection

Three separate carbon dioxide fire extinguishing systems are provided. All three systems are arranged for remote automatic electrical operation and for local manual operation.

One CO_2 system for protection of the generators consists of an initial and a reserve bank, each containing fourteen 50-pound cylinders, and a delayed discharge bank of 10 cylinders. The initial bank is arranged for the simultaneous discharge of 14 cylinders to any generator. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent release.

The second system consists of 1 bank of 20 cylinders. Twelve cylinders can be discharged into the insulating oil purification room; 20 cylinders can be discharged into the insulating oil storage room; and 8 cylinders can be discharged into the gas-electric generator room.

The third system consists of one bank of four cylinders and is arranged for the release of all four cylinders into either the lubricating oil purification room or the lubricating oil storage room.

Portable carbon-dioxide fire-extinguishing units are conveniently located in the powerhouse and switchyard. There is one 100-pound wheel-type unit for the switchyard and one for the transformer yard.

A supply of treated water with hydrants and hose connections was provided for general fire protection in the powerhouse, switchyard, and transformer yard. Eight fire hose racks in the powerhouse are equipped with a valve, 50 feet of fire hose, and a nozzle. A fire hose cart with 100 feet of 2½-inch hose and nozzles is stored in the fire equipment building located in the switchyard and the transformer yard. The switchyard is furnished with four 4-inch fire hydrants, and the transformer yard has three 2½-inch hose connections.

Service equipment

The machine shop, which is conventional size and in the service bay adjacent to the erection bay, contains the equipment listed in table 14, page 626.

An automatic push button-controlled elevator, having a live load of 5,000 pounds at a speed of 100 feet per minute serves the powerhouse and control building. The total lift is 56 feet with the top landing at elevation 824, the bottom landing at elevation 768, and three intermediate landings. Design data covering this machine are included in table 6, page 394.

The emergency auxiliary power generating unit which is installed in the service bay has a generator rating of 300 kilovolt-amperes at 0.8 power factor with direct-connected exciter, and a 6-cylinder engine rated at 410 brake-horsepower.

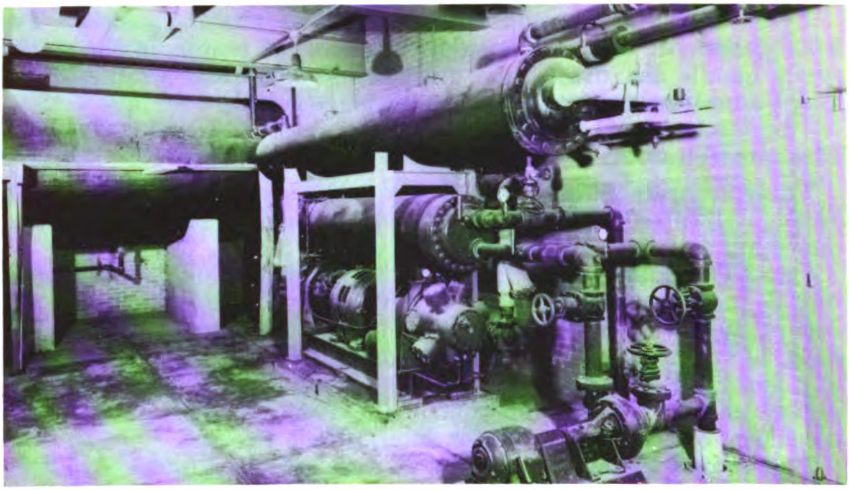


FIGURE 95.—*Fort Loudoun—air-conditioning equipment room.*

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, telephone room, reception room, and offices. The remainder of the powerhouse is mechanically ventilated. Electric unit heaters throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles serve to supplement the permanently connected heaters as required.

The air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system. A view of the air-conditioning equipment room on the elevation 783.5 floor is shown in figure 95.

The main generator leads to the step-up transformer are cooled by mechanically supplying filtered air through the leads housings to the transformer yard. During cold weather this warmed air is returned to the powerhouse to conserve heat.

A summary of the system capacities is as follows:

Cubic feet per minute of air supplied and exhausted	331,084
Kilowatts of installed electric heating	627
Horsepower of refrigeration	75

KENTUCKY

Kentucky Reservoir, the lowermost and largest of the Tennessee River system, is the key to effective control of discharges from the valley for the reduction of flood crests on the lower Ohio and Mississippi Rivers, and provides 4,010,800 acre-feet of controlled storage. Kentucky Dam (fig. 96) on the Tennessee River at river mile 22.4, is situated in the headwater of a low navigation dam on the Ohio

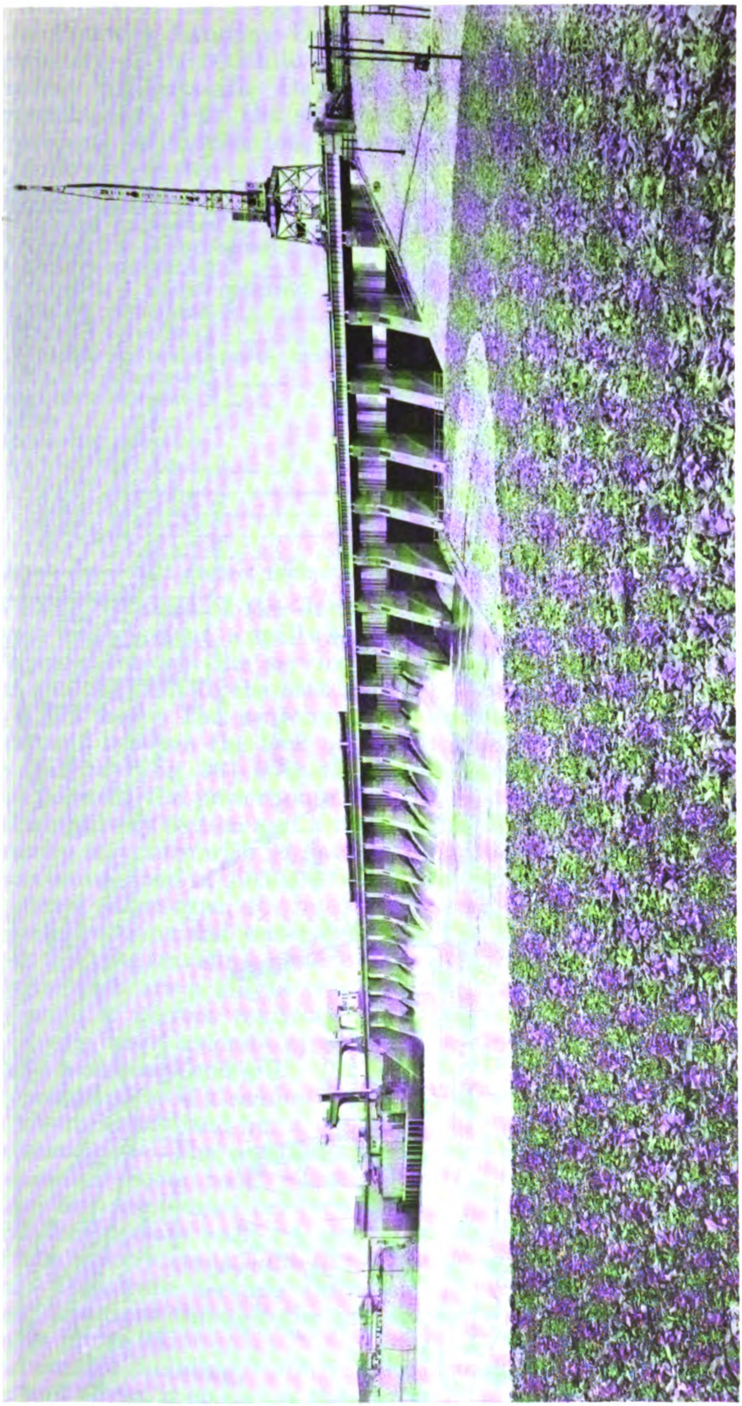


FIGURE 96.—*Kentucky project about 6 months after closure of dam.*

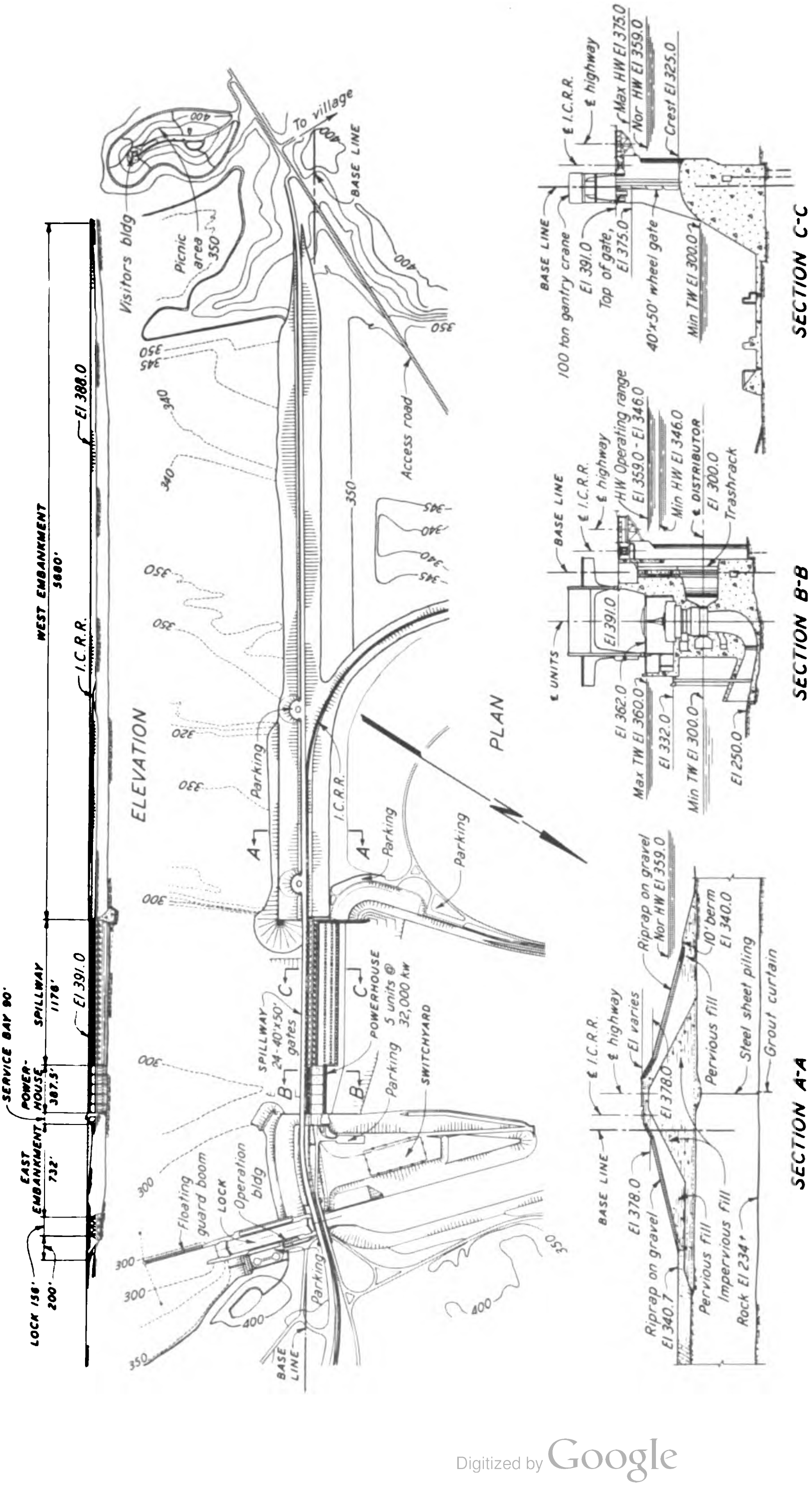


FIGURE 97.—*Kentucky—plan, elevation, and sections.*

River and extends the 9-foot navigable channel a distance of 184.3 miles to Pickwick Landing Dam. The five generating units add a total capaicty of 160,000 kilowatts to the system. The project was first called "Gilbertsville Dam and Reservoir" for the town of Gilbertsville, Ky., near the site, before being designated the Kentucky project. Authorization, construction, operation, and cost data are as follows:

Authorizations:	
Project authorized	December 20, 1937
Units 1 to 4 authorized	August 23, 1940
Unit 5 authorized	June 5, 1941
Units 1, 4, and 5 deferred	October 20, 1942
Unit 1 reinstated	August 28, 1943
Unit 4 reinstated	November 4, 1943
Unit 5, embedded parts, reinstated	April 14, 1944
Unit 5 reinstated	June 13, 1945
Consruction started	July 1, 1938
Closure	August 30, 1944
Commercial operation:	
Unit 3	September 14, 1944
Unit 2	November 18, 1944
Unit 1	April 6, 1945
Unit 4	December 23, 1945
Unit 5	January 16, 1948
Cost of the 5-unit project including switchyard	$119,201,268

The main features of the dam, as indicated in figure 97, consist of a west embankment, a spillway, a powerhouse and service bay, an embankment between the service bay and lock, a navigation lock, and an embankment to the east abutment, making a total length of about 8,422 feet. The switchyard is downstream from the earth embankment between the lock and service bay.

The spillway (fig. 96) is in the central portion of the main-river channel between the powerhouse and the west embankment. It consists of a spillway section and a retaining wall section. The spillway is a gravity structure with 24 gate openings, designed for the passage of a maximum flood of 1,050,000 cubic feet per second. Twenty-four 3-leaf, fixed roller type, 40- by 50-foot crest gates are provided for reservoir regulation and water control. The gates are operated from the deck by two traveling gantry cranes. Incorporated in the main dam structures are a single track railroad bridge and a highway bridge with a 28-foot roadway. To assist in energy dissipation, the spillway has a concrete apron with two rows of staggered baffle piers and a notched end sill.

The powerhouse is a semioutdoor-type structure on the right side of the river channel and has a combination gravity and buttress-type intake structure. The access to the powerhouse is at the level of the generator room roof. The generator room and downstream electrical bay are located between the downstream face of the intake and the downstream wall. A steel girder supports the downstream leg of the gantry crane, and the upstream leg is supported on the intake. The crane services the units and erection areas through hatches. Sections through the powerhouse and the service bay are shown in figure 98.

The control building, which also houses the public reception rooms and offices, is on top of the downstream end of the service bay.

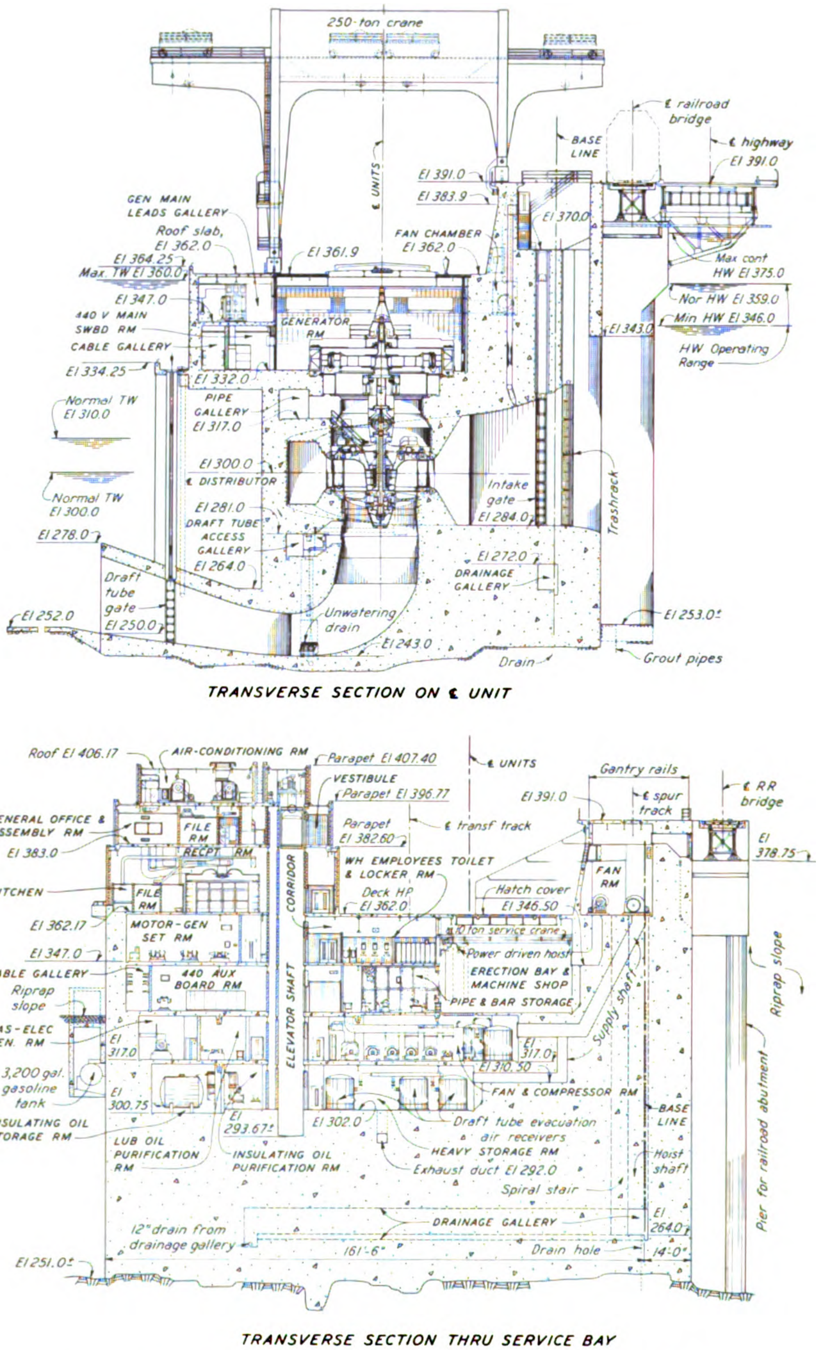


Figure 98.—*Kentucky—sections through powerhouse and service bay.*

The switchyard is on an extended fill forming a peninsula downstream from the east embankment between the powerhouse tailrace and the lower lock approach channel. The switchyard connects to the control building by a control cable tunnel. Oilostatic cables laid in the switchyard fill connect the generators with the main transformer banks in the switchyard.

Before the new lock under construction at Wilson Dam was designed the navigation lock for the Kentucky project was the only lock in the TVA system designed by TVA, the other locks having been designed by the U.S. Corps of Engineers. The lock, located in a cut on the right river bank, is 110 feet wide by 600 feet long in clear chamber dimensions and is a single-lift type with a maximum lift of 73 feet and a normal lift of 55 feet. Normal operating facilities are provided, consisting of miter lock gates, culvert and port filling and emptying system, segmental culvert valves, towing equipment, floating mooring bits, emergency unwatering dams, water level gauges, ladders, check posts, lighting fixtures, and all machinery and controls necessary for operation.

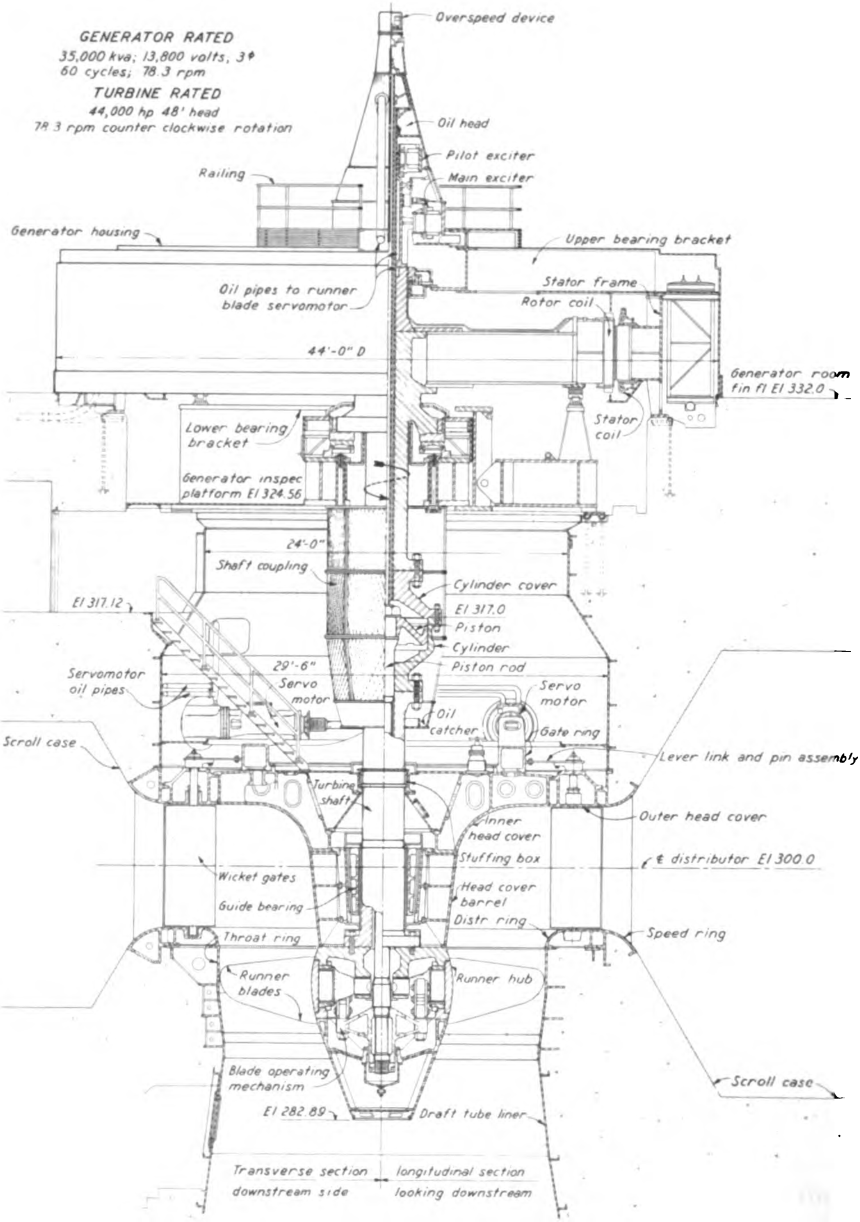
The lock operation building is on the land wall and consists of a 2-story center section, flanked by single story wings, all built over a full basement. One smaller basement room contains mechanical equipment for TVA use, and a large basement room combines storage space and space for mechanical equipment required for lock operation.

Turbines

Five Kaplan-type hydraulic turbines manufactured by the Allis-Chalmers Manufacturing Co. are direct-connected to the generators. The turbines are rated 44,000 horsepower at a net head of 48 feet and operate at a speed of 78.3 revolutions per minute. They are designed to operate under any head from a minimum of 6 feet to a maximum of 58.5 feet with a minimum of 10,500 horsepower at a net head of 20 feet. They are also designed to withstand a maximum runaway speed of 220 revolutions per minute. At rated conditions the value of specific speed is 130, and the center line of the runner is approximately 13 feet below normal tailwater elevation giving a plant sigma of 0.96.

The Kentucky units (fig. 99) have concrete spiral cases with cast-steel stay rings. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners each have six cast-steel blades set in a cast-steel hub which contains the blade-operating mechanism. Certain areas on the back side of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is guided by a water-lubricated bearing of molded plastic material or Insurok located in the bore of the head cover barrel. Figure 100 shows an assembled runner, shaft, and head cover in transit on the powerhouse crane.

Efficiency acceptance tests were made at the manufacturer's hydraulic laboratory on a homologous model which indicated that the prototype would exceed the efficiency and capacity guarantees.



GENERATOR - TURBINE SECTION

FIGURE 99.—*Kentucky—generator-turbine sections.*

Governors

The governors are the cabinet-actuator type manufactured by the Allis-Chalmers Manufacturing Co. A single actuator cabinet is provided for unit 1, a twin cabinet for units 2 and 3, and a twin cabinet for units 4 and 5. Each governor is complete with governor head, pressure tank, sump tank, potential transformer for driving the governor head, and the necessary auxiliaries for control of the turbine from the actuator. The twin governors have interconnected oil pressure systems so that both governors may be operated from one oil pump, and the single governor is provided with 2 oil pumps, 1 of which functions as a spare. Each oil pump has a capacity of 275 gallons per minute at a pressure of 300 pounds per square inch and is driven by a 75-horsepower motor. The pressure tanks have a volume of 384 cubic feet each. The twin governor sump tanks have a volume of 785 cubic feet, and the single governor sump tank has a volume of 500 cubic feet.

Generators

The five generators, manufactured by the General Electric Co., have a normal rating of 35,000 kilovolt-amperes or 32,000 kilowatts at 0.915 power factor, 60 cycles, 3 phase, 13,800 volts, and 78.3 revolutions per minute. Each generator is the vertical type with combination Kingsbury-type thrust and segmental guide bearings located below the rotor and an additional guide bearing above the rotor. The generator is totally enclosed, air cooled, with water-cooled heat exchangers within the housing. Figure 99 shows sections of a unit.

The combination thrust and guide bearing below the rotor is immersed in oil, which is cooled by water coolers in the oil reservoir. The oil-immersed guide bearing located above the rotor is shoe type and self-cooled.

A braking ring is provided on the underside of the rotor. Four

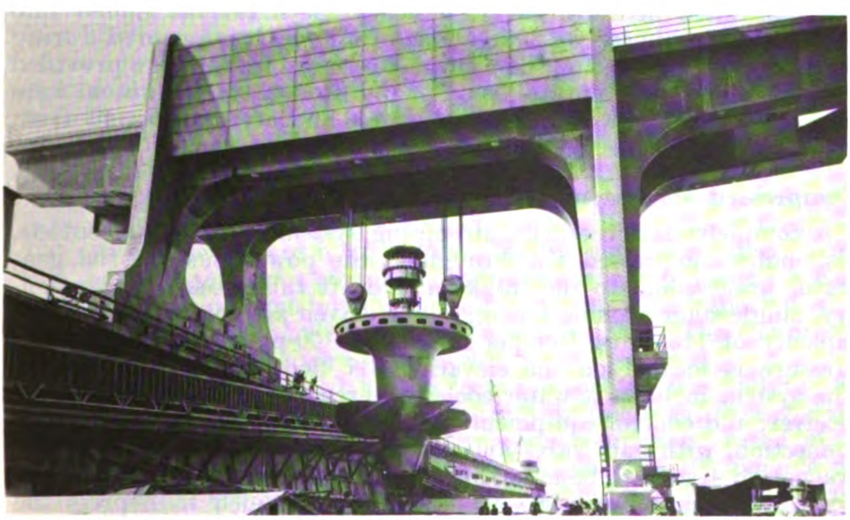


FIGURE 100.—*Transporting Kentucky turbine runner with powerhouse crane.*

combination brakes and jacks are mounted on the thrust bearing bracket main beams, with two additional jacks on the bracket side-arms. Compressed air at 100 pounds per square inch for braking is supplied from the station air service system and manually controlled at the actuator. Oil pressure for jacking is applied by means of a portable hand-operated oil pump.

Fire protection is provided from a carbon dioxide fire extinguishing system. Nozzles are located in ring headers above and below the rotor.

A view of the generator room with unit 1 in the foreground is shown in figure 101.

Oil systems

The governor and lubricating oil system consists of one 350-gallon-per-hour purifier; 1 clean- and 1 dirty-oil pump, each of 30-gallon-per-minute capacity; 1 clean- and 1 dirty-oil storage tank, each of 5,100-gallon capacity; and the necessary connecting piping for the supply and return of oil to any unit generator bearing or governor system. The lubricating oil purifier, pumps, and storage tanks are located on the elevation 317 floor of the service bay.

The insulating oil system consists of one 100-gallon-per-minute pump for clean-oil handling only, an insulating oil purifier with a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press, storage facilities, and a complete piping system for supply and return of insulating oil to the electrical equipment in the switchyard. The storage tanks, located in the insulating oil storage room at elevation 300.75, consist of four 6,450-gallon-capacity oil tanks, 2 of which are for dirty transformer oil, 1 for dirty circuit breaker oil, and 1 for clean insulating oil. Connections for filling and draining the electrical equipment are made with flexible hose to conveniently located valve boxes. The equipment is drained by gravity to the dirty-oil tanks or purifier.

A permanent pipe header for filling and draining the runner hub oil is installed in the drainage gallery. Each turbine runner hub contains approximately 1,600 gallons of oil which is removed during inspection or dismantling of a unit. Hose connections are provided for the use of the portable pump and storage tanks which were purchased for Pickwick Landing project and are transported from project to project as required.

Compressed air systems

A complete station service air piping system, with service outlets, distributes compressed air throughout the powerhouse, to the generator brakes, and to the intake and draft tube decks. A stationary, single-stage, double-acting, motor-driven air compressor with a capacity of 113 cubic feet per minute at 100-pound-per-square-inch pressure is located on the elevation 317 floor of the service bay. The system includes a water-cooled aftercooler, a 150-cubic-foot air receiver, and control equipment for automatic operation. An interconnection, with gate valve and check valve, permits the draft tube evacuation system to be used as a standby for the station air system.

A draft tube evacuation air system is provided to depress the water level in the draft tubes for operation of the units as syn-

FIGURE 101.—*Kentucky generator room.*

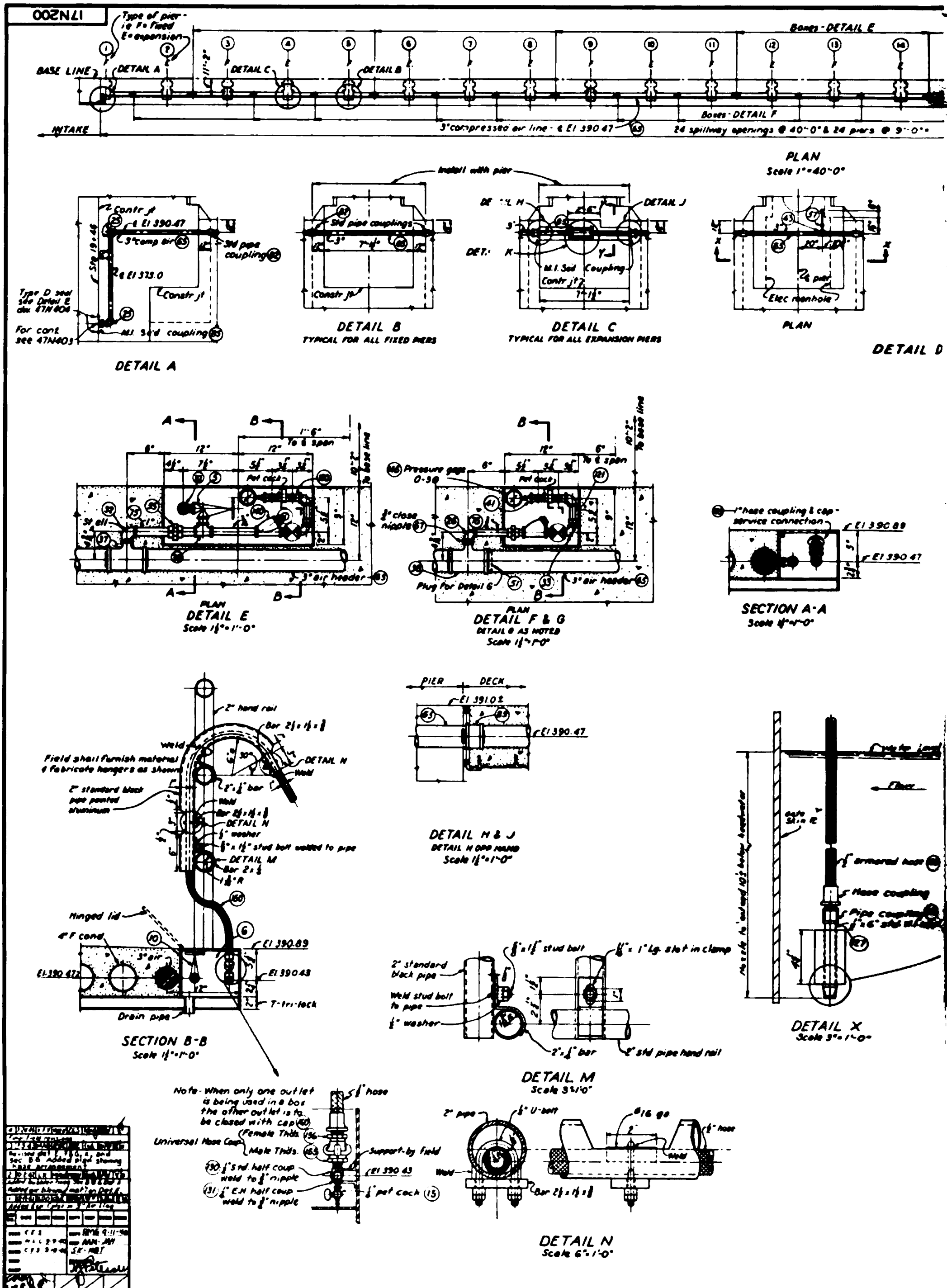
chronous condensers. The compressor is a stationary, single-stage, double-acting, motor-driven unit with a capacity of 343 cubic feet per minute at 100-pound-per-square-inch discharge pressure. Six air receivers with 3,000 cubic feet of storage capacity are on the elevation 302 floor of the service bay. The system includes a water-cooled aftercooler and control equipment for automatic operation of the compressor. A float switch and solenoid-operated regulating valves are provided for remote manual control of the evacuation system from the actuator cabinet. An interconnection and valve between this system and the spillway bubbler air system permit the duplicate compressor for the bubbler system to be used as a standby.

A spillway bubbler air system is furnished for preventing the formation of ice on the spillway gates. The compressor, after-cooler, and control equipment are duplicates of and installed adjacent to those furnished for draft tube evacuation. A storage receiver of 500-cubic-foot capacity and a pressure reducing valve station are located near the compressor. A complete piping system furnishes compressed air to valved outlets on the spillway deck. A complete description of this system is given in chapter 7, "Compressed Air Systems," and some of the details are shown in plate 1.

A portable, air-cooled, motor-driven air compressor, having a capacity of 82 cubic feet per minute and a discharge pressure of 100 pounds per square inch, is available for general service.

A separate governor compressed air system is supplied by a compressor of approximately 13-cubic-foot-per-minute capacity at a discharge pressure of 300 pounds per square inch. The compressor is complete with receiver and controls.

Compressed air is used at the lock for tool service and for the air-operated signal horn. The air supply is furnished by a 2-stage, air-cooled, single-acting, motor-driven air compressor rated at 60 cubic feet per minute and a discharge pressure of 100 pounds per square inch. The system includes a 45-cubic-foot air receiver and control equipment for automatic operation. A complete piping system supplies air to the various hose outlets throughout the lock.



17N200
PLAN
Scale 1" = 40'-0"
DETAIL A
DETAIL B
TYPICAL FOR ALL FIXED PIERS
DETAIL C
TYPICAL FOR ALL EXPANSION PIERS
DETAIL D
PLAN
DETAIL E
Scale 1½" = 1'-0"
PLAN
DETAIL F & G
Scale 1½" = 1'-0"
SECTION A-A
DETAIL H & J
Scale 1½" = 1'-0"
SECTION B-B
Scale 1½" = 1'-0"
DETAIL M
Scale 3" = 1'-0"
DETAIL X
Scale 3" = 1'-0"
DETAIL N
Scale 6" = 1'-0"
3" compressed air line
24 spillway openings @ 40'-0" & 24 piers @ 9'-0"

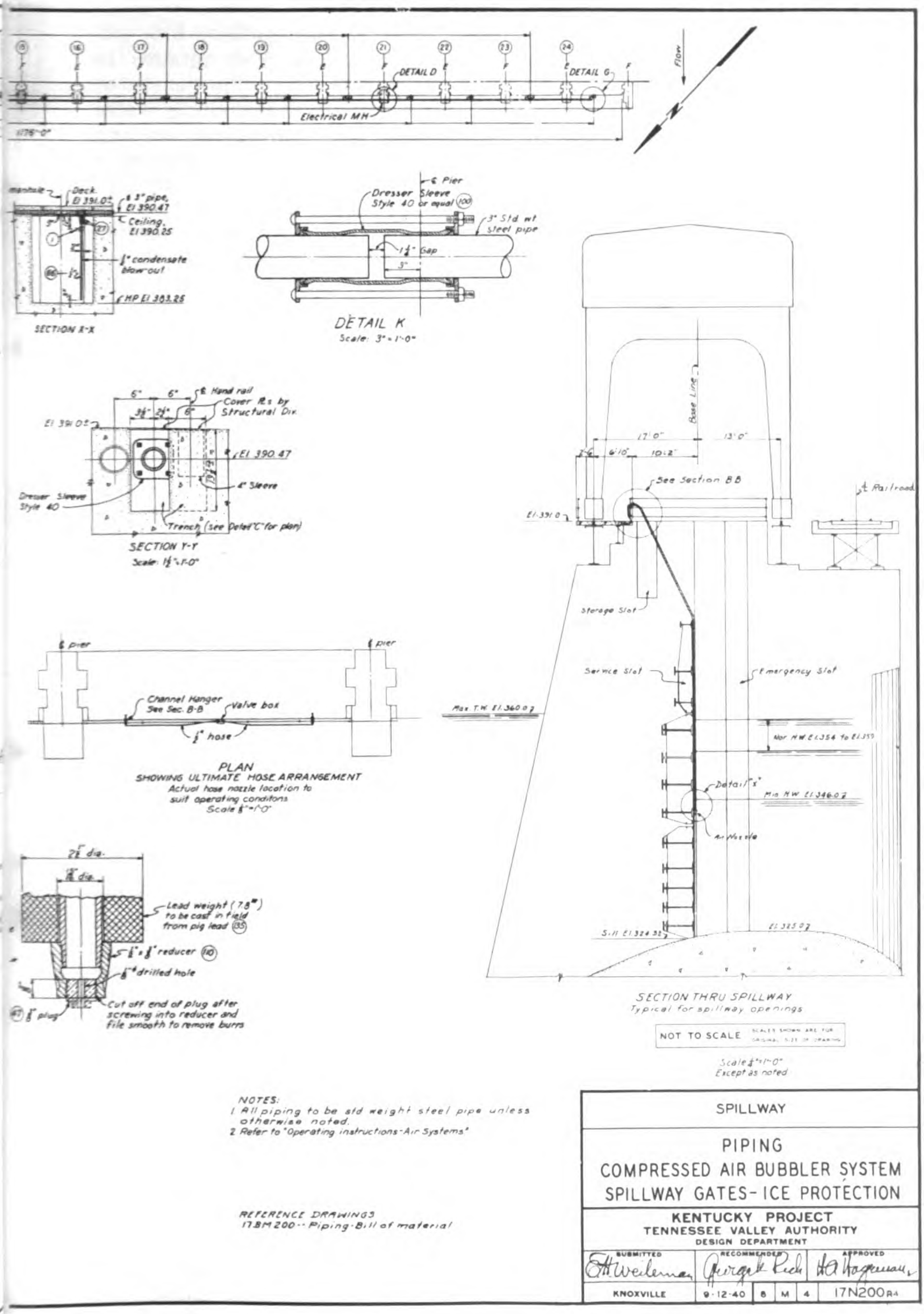

DETAIL D
DETAIL G
Electrical MH
Flow
Deck El 391.0"
3" pipe, El 390.47
Ceiling, El 390.25
condensate blow-out
HP El 383.25
SECTION X-X
Pier
Dresser Sleeve Style 40 or equal
3" Std wt steel pipe
Gap
DETAIL K
Scale: 3" = 1'-0"
Hand rail
Cover Pls by Structural Div.
El 391.0
El 390.47
4" Sleeve
Dresser Sleeve Style 40
Trench (see Detail "C" for plan)
SECTION Y-Y
pier
Channel Hanger See Sec. B-B
Valve box
hose
PLAN
SHOWING ULTIMATE HOSE ARRANGEMENT
Actual hose nozzle location to suit operating conditions
Lead weight (7.8#) to be cast in field from pig lead
reducer
drilled hole
Cut off end of plug after screwing into reducer and file smooth to remove burrs
plug
Base Line
17'0"
13'0"
See Section BB
Railroad
El 391.0
Storage Slot
Service Slot
Emergency Slot
Max. T.W. El 360.0
Nor. H.W. El 354 to El 359
Detail "X"
Min. H.W. El 346.0
Air Nozzle
Sill El 324.32
SECTION THRU SPILLWAY
Typical for spillway openings
NOT TO SCALE
Scale 1/8"=1'-0"
Except as noted
NOTES:
1. All piping to be std weight steel pipe unless otherwise noted.
2. Refer to "Operating instructions-Air Systems"
REFERENCE DRAWINGS
17BM200 -- Piping-Bill of material
SPILLWAY
PIPING
COMPRESSED AIR BUBBLER SYSTEM
SPILLWAY GATES-ICE PROTECTION
KENTUCKY PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
9-12-40
17N200 R4

PLATE 1

Raw water system

Normal unit cooling water supply is obtained from intakes in each unit scroll case, strained, and pumped through the generator air and oil coolers by the 1,200-gallon-per-minute unit cooling water pumps, discharging back to the scroll case. An emergency cooling water pump with a raw water intake in the forebay and having a capacity of 1,200 gallons per minute is in the service bay. It supplies the emergency cooling water header, which has connections to each unit, and serves as a standby unit. In addition, interconnections permit the use of other unit cooling water systems for emergency supply. Turbine raw water requirements for the stuffing box, water-lubricated bearing, and wheel pit eductor are also supplied from the scroll case intake. The raw water flows by gravity through separate twin strainers to each turbine. Interconnections supply the turbine raw water from the emergency cooling water header.

Cooling water for the air compressors, aftercoolers, gas-electric generator set, and the air-conditioning equipment is supplied by gravity from the forebay intake and strainer serving the emergency cooling water pump.

The raw water supply lines for the turbines, generator air coolers, generator bearing oil coolers, and gas-electric generator set have their own series of alarm circuits operated by flowmeters, flo-sigs, or pressure switch to indicate low flows. The flo-sigs in the turbine bearing water supply lines have an additional contact to shut down or prevent starting the units on low flow.

The oilostatic generator leads were modified to include circulation and cooling of the oil in the buried sections outside the powerhouse as a means of adapting the capacity of the leads to increased generating loads. Pumps were installed to circulate oil from the long buried sections of the leads through coolers. Raw water from the forebay intake is supplied normally by gravity through the cooling water pump bypass. A 60-gallon-per-minute cooling water pump, located on the elevation 317 floor of the service bay, is provided for operation during periods of low headwater.

A lawn sprinkler pump which supplies the east embankment lawn sprinklers is in the TVA space in the basement of the lock operation building. The pump, which draws its water supply from headwater, has a capacity of 150 gallons per minute. Another pump, for fire protection, flushing decks, etc., with a capacity of 125 gallons per minute, is located in the lock operator's space in the basement of the operations building and utilizes the same intake as the lawn sprinkler pump. A complete piping system is provided with various outlets throughout the lock.

Treated water system

The treated water facilities, located on the west embankment, consist of a 200-gallon-per-minute deepwell type raw water pump, a 100,000-gallon elevated storage tank, and a filter plant of 200-gallon-per-minute maximum capacity. A complete piping system supplies treated water to the lock, powerhouse, switchyard, picnic and parking areas, boat basin, and Kentucky Village. The filter plant is a conventional type consisting of a coke tray aerator, a water-soften-

ing and settling tank, a 2-bed rapid sand gravity filter, dry chemical feeders, hypochlorinator for feeding hexametaphosphate, clorinator, clearwell, an 800-gallon-per-minute wash water pump, and two 250-gallon-per-minute service pumps.

Treated water is used for all sanitary, fire protection, and general services in the powerhouse, service bay, control building, lock, Kentucky Village, picnic area, boat basin, and for all drinking fountains. Treated water is also used for part of the lawn-sprinkling system and part of the air-conditioning equipment. Service outlets on the intake gate pit deck and draft tube deck are also supplied from this system.

Sewage disposal

The waste from the powerhouse sanitary fixtures discharges into a 2,750-gallon metal septic tank located in the service bay at elevation 317. Under normal conditions of tailwater, the effluent from the septic tank drains directly into the tailrace by gravity through an outlet in unit 1 draft tube pier. When tailwater rises above elevation 317, the effluent is diverted to the station sump from which it will be automatically discharged to tailwater by the station drainage pumps.

The waste from the toilet fixtures located on the generator room floor at unit 3 drains directly into the tailrace by gravity through an outlet in the draft tube pier. During high tailwater a valve in the waste line is closed to prevent water backing up into the fixtures, the use of the facilities being discontinued.

The waste from the lock operation building sanitary fixtures discharges into a 900-gallon steel septic tank in the basement of the building. The effluent from the tank discharges into the lock through a 4-inch cast-iron pipe.

The waste from the toilet fixtures in the public safety service headquarters and public toilet building discharges into a 4,000-gallon septic tank located adjacent to the east end of the building. The septic tank is provided with a siphon, and the effluent is discharged into a subsurface tile field with a 6-inch underdrain terminating in gravel fill under the riprap on the downstream side of the lock.

Drainage and unwatering

Powerhouse unit bay drainage below elevation 360, which is the design maximum tailwater elevation, is drained to the station sump. Powerhouse roof drainage flows directly to tailwater. All service bay roof and deck drains and the plenum drains from the air-conditioning room at elevation 395.75 drain directly to tailwater or to the forebay where possible. Other service bay drainage, including the septic tank effluent, from the elevation 317 floor or above normally drains directly to tailwater, but it may be bypassed into the station sump when tailwater rises above elevation 317.

The station drainage and unwatering sump is in the basement of the service bay. It has a capacity of approximately 15,825 gallons and is serviced for normal station drainage by two 300-gallon-per-minute, deepwell, turbine-type pumps discharging directly to tailwater. The pumps are operated automatically by float controls.

Drainage from the spillway and intake drainage gallery is normally carried to the station sump through a 12-inch drain line, which is provided with a 12-inch equalizing outlet to tailwater. If an excessive amount of leakage accumulates in the gallery during high water periods, it may be necessary to allow the gallery to fill up to tailwater level by closing the valve in the 12-inch line emptying into the station sump and allow the excess to equalize to tailwater. Another 12-inch equalization line from the gallery to tailwater is placed in the west abutment wall of the spillway, with a check valve and operating valve in the gallery. The operating valve is normally open to allow excess leakage to equalize to tailwater, thus preventing any buildup of pressure or uplift on the spillway structure greater than that produced by tailwater. This system also prevents exceeding the pumping capacity of the station drainage sump, which would cause flooding portions of the powerhouse.

The turbine pit at each unit is unwatered by a 1¼-inch jet ejector discharging into the wheel pit drainage system, which flows to the station sump.

An unwatering system for all draft tubes and scroll cases is provided to permit inspection and repair of turbine runners which are below the normal tailwater elevation. In the floor of each scroll case is a drain outlet and a 16-inch drain line with a shutoff valve. When the head gates are closed, the water in a scroll case comes to tailwater level through the wicket gates and through the 16-inch drain line emptying into its draft tube. Each draft tube has a drain outlet approximately two feet above the low point. A 16-inch pipe, with control valve, connects the outlet to a 20-inch header which connects through its own control valve directly to the suction line of two 5,390-gallon-per-minute deepwell turbine-type unwatering pumps in the station drainage and unwatering sump. Unwatering valves are operated from the unwatering gallery.

Each unwatering pump is manually operated and discharges directly to tailwater. Either of these pumps may be used to augment the station drainage system pumping capacity by means of a strained suction inlet and valved connection from the sump to the pump suction line.

Fire protection

Two separate carbon-dioxide fire-extinguishing systems are provided. Both systems are arranged for remote automatic electrical operation and for local manual operation.

One system, for protection of the generators, is in the electrical bay near unit 4 and consists of three banks of 50-pound cylinders—an initial discharge bank and a reserve bank, each consisting of thirty cylinders, and a delayed discharge bank of twenty cylinders. The initial bank is arranged for the simultaneous discharge of thirty cylinders to any generator. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent release of cylinders to maintain sufficient concentration.

The second CO_2 system, for protection of the oil storage, the oil purification, and the gas-electric generator rooms, is in the service bay and

consists of one bank of fourteen 50-pound cylinders. The system is arranged for the release of 7 cylinders into the gas-electric generator room, or 4 into the lubricating oil purification room, or 7 into the lubricating oil storage room, or 4 into the insulating oil purification room, or all 14 into the insulating oil storage room. Any two of these rooms other than the insulating oil storage room may be flooded with carbon dioxide at the same time.

Portable carbon-dioxide fire-extinguishing units are conveniently located in the powerhouse and switchyard.

Treated water is supplied for general fire protection in the powerhouse and switchyard. Ten fire hose outlets, each equipped with a valve, 50 feet of fire hose on a rack, and a nozzle are placed at convenient locations throughout the building. In the switchyard treated water is available for fire protection from four fire hydrants. Two fire hose carts, each complete with wrenches, reels, 100 feet of hose, and two nozzles, are provided. These carts are stored in two small concrete fire-protection equipment buildings with the carbon-dioxide equipment.

Service equipment

The machine shop, which is conventional size and located in the service bay adjacent to the erection bay, contains the equipment listed in table 14, page 626.

An automatic push button-controlled elevator, having a live load capacity of 2,500 pounds at a speed of 300 feet per minute, is provided for the powerhouse. The elevator, with a total lift of 81 feet, has landings at all six floor levels of the powerhouse and control building. Design data covering this machine are included in table 6, page 394.

The emergency auxiliary power generating unit, which is installed in the service bay on the elevation 317 floor, has a 400-kilovolt-ampere generator operating at 0.8 power factor and driven by a 565-brake-horsepower, 8-cylinder gasoline engine at 1,200 revolutions per minute.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, telephone room, reception room, and offices and the remainder of the powerhouse is mechanically ventilated. Electric unit heaters throughout the powerhouse heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters serve to supplement the permanently connected heaters as required.

The air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system.

A summary of the design capacities of these systems is as follows:

Cubic feet per minute of air supplied and exhausted	485,250
Kilowatts of installed electric heating	683
Horsepower of refrigeration	75

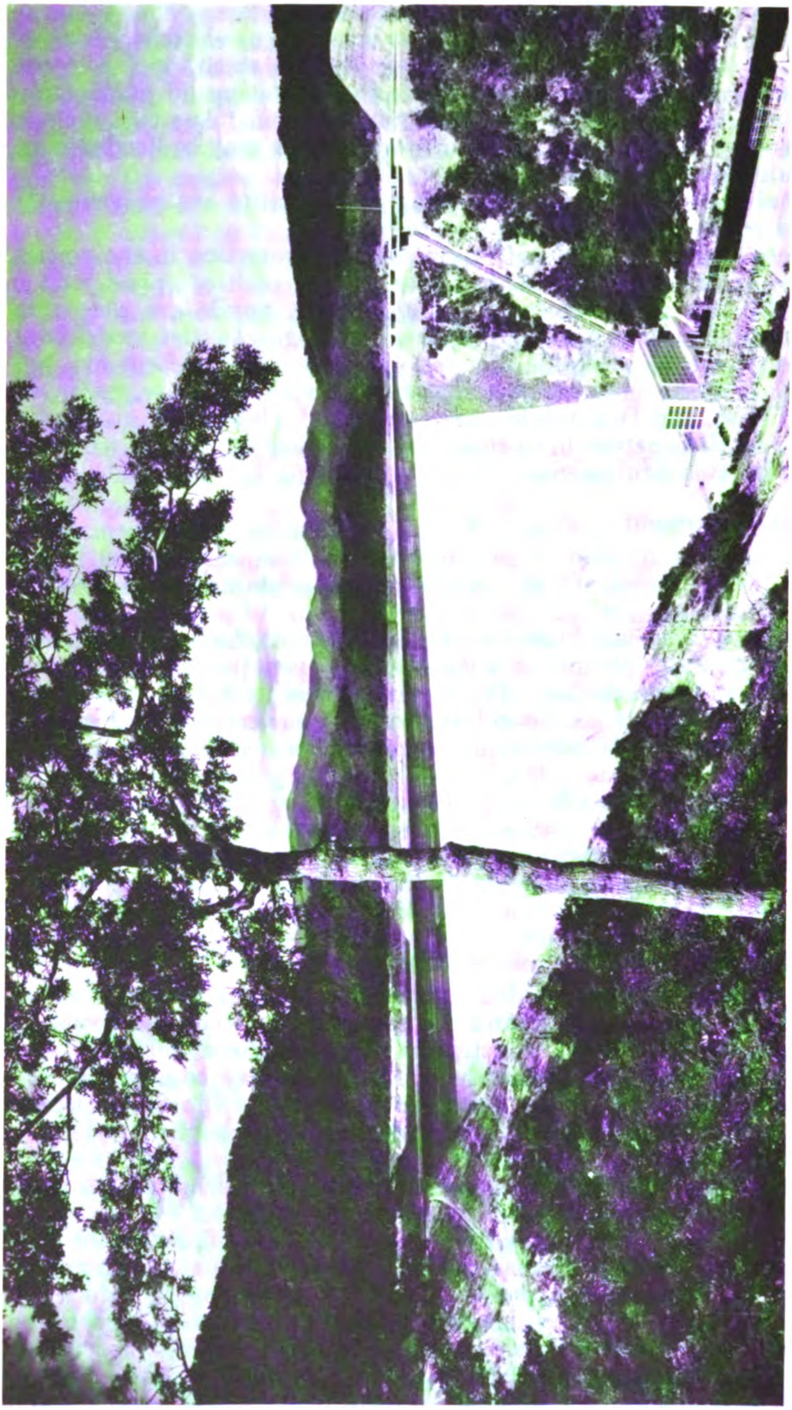


FIGURE 102.—*Fontana project.*

FONTANA

Fontana project (fig. 102), located on the Little Tennessee River at river mile 61 in western North Carolina, was built primarily for flood control and power generation. Authorized as part of the third World War II emergency program, the project has a useful controlled storage volume of 1,157,300 acre-feet and adds a generating capacity of 202,500 kilowatts to the system. At the time of construction, Fontana Dam was the fourth highest in the world and the highest dam in the United States east of the Rocky Mountains with a maximum height of 480 feet above foundation rock. Authorization, construction, operation, and cost data are as follows:

Authorization:	
Project and units 1 and 2	December 23, 1941
Unit 3	September 6, 1950
Construction started	January 1, 1942
Closure	November 7, 1944
Commercial operation:	
Unit 1	January 20, 1945
Unit 2	March 24, 1945
Unit 3	February 4, 1954
Cost of the 3-unit project, including switchyard	$75,680,643

The principal features of the project, shown in figures 103 and 104, include: the main dam across the river valley; the powerhouse and switchyard located at the foot of the dam; and various outlet structures consisting of the main spillway, an emergency spillway, and a low level outlet.

The main dam is a straight gravity concrete structure (fig. 105), the nonoverflow type, with a maximum height of 480 feet from foundation rock to the roadway on top and a maximum base width of 377 feet. The total overall length of the dam structures, including the main spillway and left abutment sections, is 2,365 feet. Three blocks in the main dam section are used as the intake for the powerhouse. They each contain a trashrack, an intake gate and gate operating machinery, and a 14-foot-diameter steel penstock. The tractor-type intake gates operate in slots in piers on the face of the intake structure. Each gate is operated by a fixed hoist mounted in a hoist chamber.

As shown in figure 106, the powerhouse is the indoor type with a reinforced concrete superstructure. It is adjacent to the toe of the dam. Adjoining the units on each end are wings for station service facilities, and the space between the powerhouse and the dam forms an equipment bay. An inclined railway was built for elevator service between the powerhouse and a visitors' building on the left abutment but a car for the incline has not yet been purchased. The switchyard is adjacent to the powerhouse on the right bank, as shown in figure. 105.

The spillway control structures are located in the low concrete dam along the ridge at the left abutment. Four ogee-type overfall sections and six sluices discharge into two concrete-lined inclined tunnels, 34 feet in diameter. The spillway tunnels connect with two plugged diversion tunnels which were located under the left abutment with outlets at the river bank 600 feet downstream from the powerhouse. Flow of water through each tunnel is regulated

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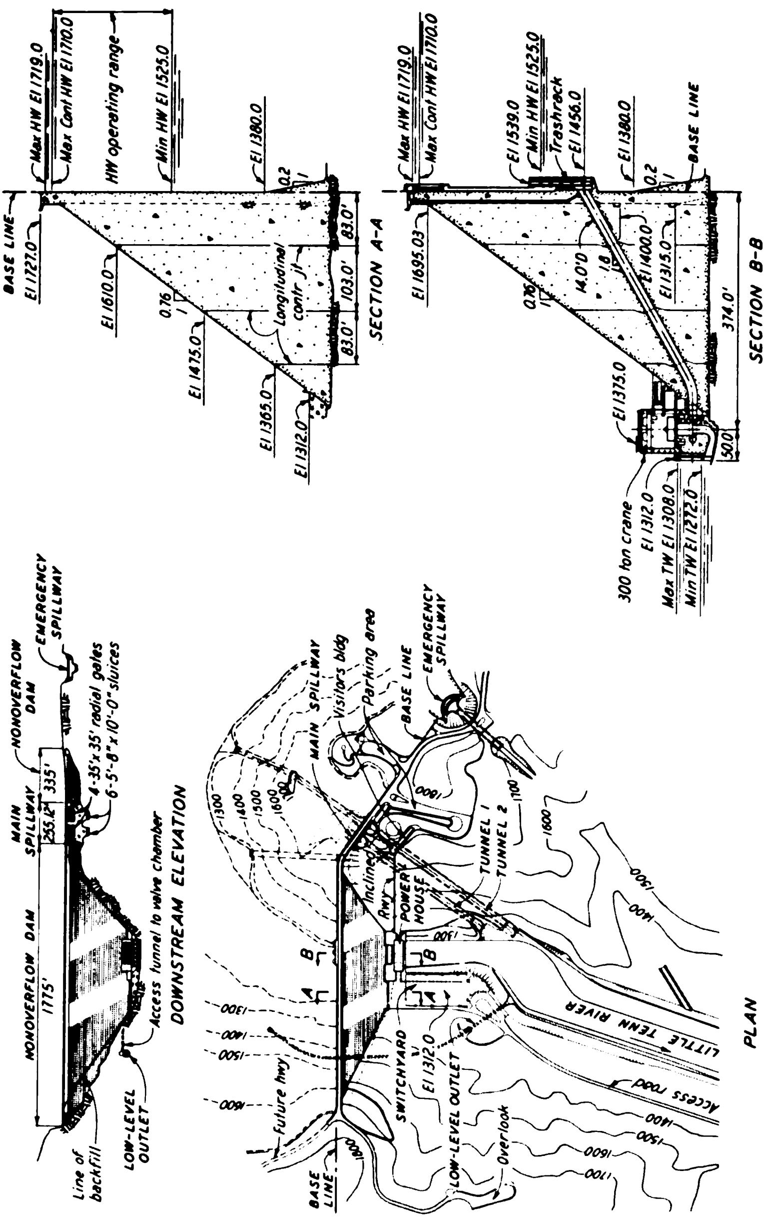


Figure 103.—*Fontana—plan, elevation, and sections.*

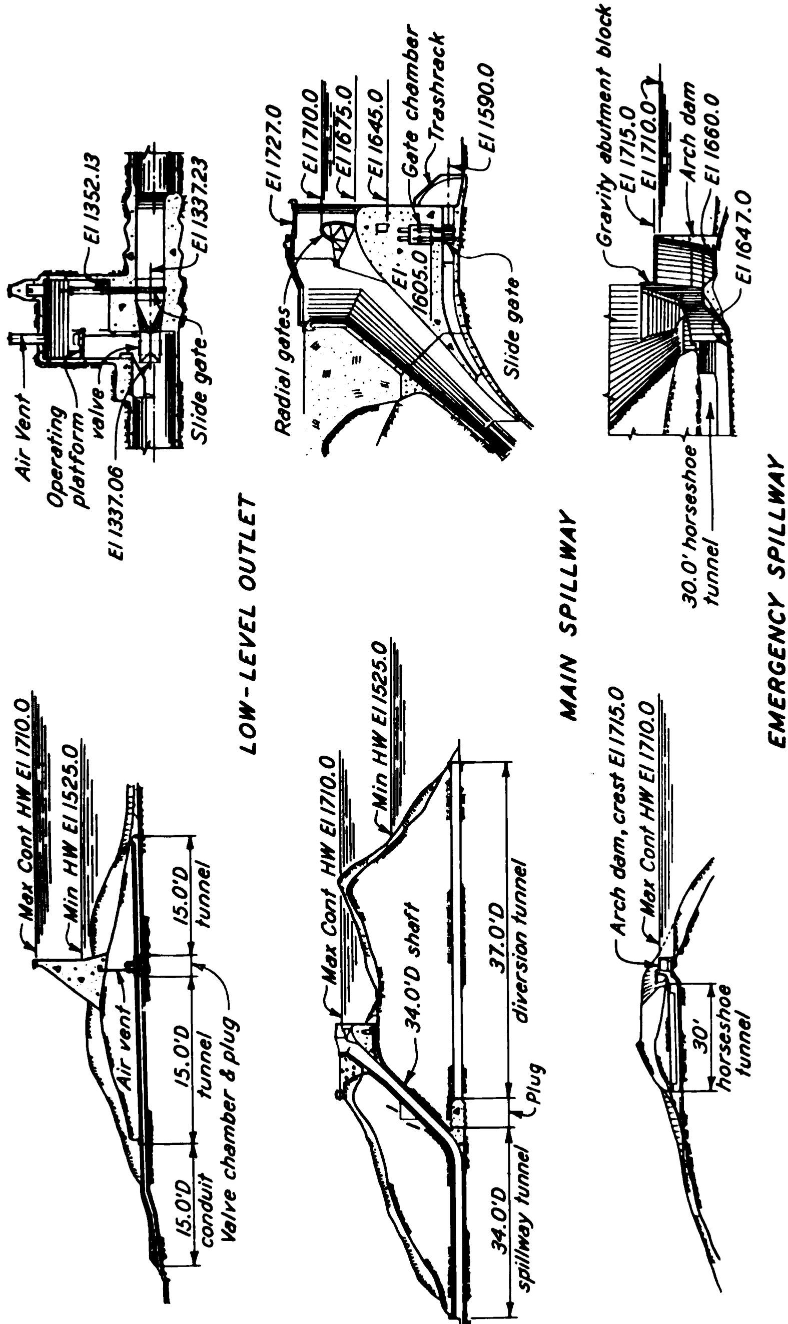


FIGURE 104.—*Fontana—spillway and outlet structures.*

by two 35- by 35-foot crest gates of the radial type and by three slide gates placed in three sluice openings, 5 feet 8 inches wide by 10 feet high, with center lines at elevation 1590. Each sluice is protected by trashracks, and the slide gates are hydraulically operated. At the outlets, bucket-shaped aprons direct the water into the natural river channel and discharge water upward into the air for energy dissipation.

An emergency spillway, located 1,000 feet southeast of the main spillway on the left abutment, consists of a concrete arch dam with a free crest 181 feet long at elevation 1715. When the reservoir level rises more than 5 feet above the maximum controlled headwater level (elevation 1710), water overflows the crest of this structure, drops into a cushion pool, and discharges through a 30-foot-wide by 27-foot-high horseshoe-shaped, partially lined tunnel into a natural draw with outlet to the river 1,600 feet downstream from the powerhouse.

In order to permit discharge during periods of low reservoir level, there is a low level outlet located under the right abutment. It consists of a 15-foot-diameter concrete-lined tunnel and a reinforced concrete conduit extending through the downstream riverbank. Flow is controlled by an 84-inch Howell-Bunger valve. Two steel-lined longitudinal baffles, projecting from the roof, are utilized to control the discharge at the valve outlet. A hydraulically operated slide gate located upstream at the valve inlet serves as an emergency gate. A valve chamber above the downstream end of the tunnel plug furnishes space for the operating machinery.

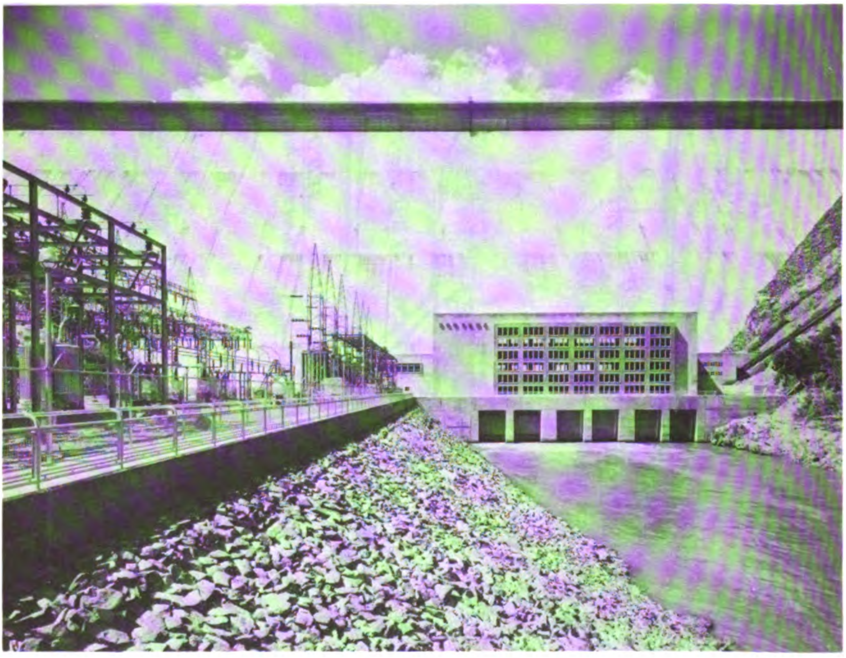


FIGURE 105.—*Fontana—switchyard and powerhouse at foot of dam.*

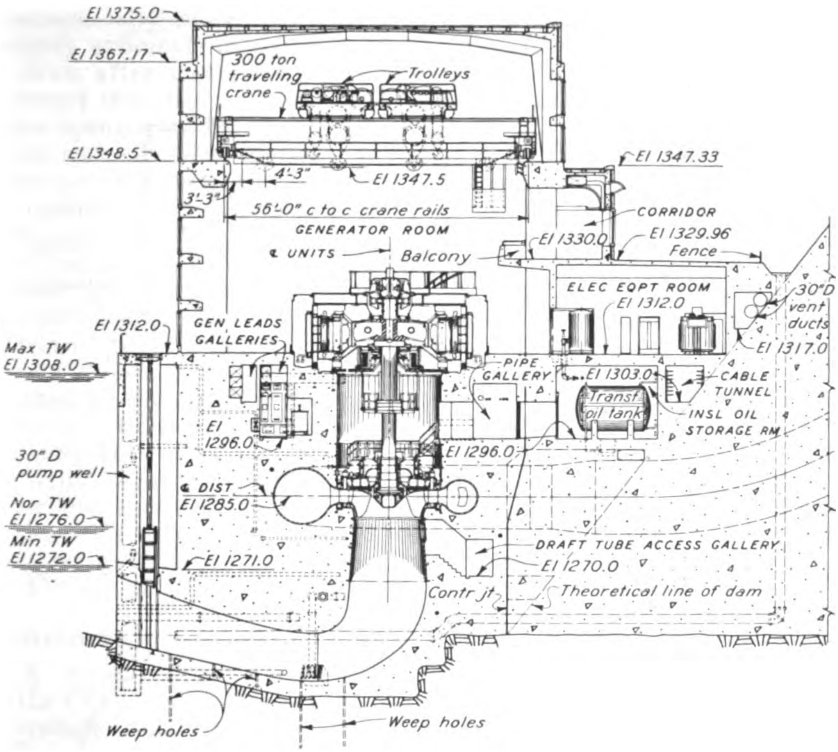


Figure 106.—*Fontana powerhouse cross section.*

With the reservoir level at elevation 1720, the combined discharge capacity of the ogee spillway and sluices is 184,000 cubic feet per second, and the emergency spillway will discharge 7,000 cubic feet per second. In addition, the low level outlet has a maximum discharge capacity of about 5,000 cubic feet per second.

Turbines

Three vertical Francis type hydraulic turbines manufactured by the Allis-Chalmers manufacturing Co. are direct-connected to the generators. The turbines are rated 91,500 horsepower at a net head of 330 feet and operate at a speed of 150 revolutions per minute. They are designed to operate under any head from a minimum of 235 feet to a maximum of 420 feet and are most efficient at a net head of approximately 355 feet. At rated conditions the value of specific speed is 32, and the centerline of the runner is set about 6 feet above normal tailwater elevation giving a plant sigma of 0.078. Sections of the turbine and generator are shown in figure 107.

The cast-steel stay ring forms the main foundation ring for the turbine, and the 20 stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. The spiral case is welded plate-steel construction and is welded to the stay ring. The spiral case and stay ring were subassembled

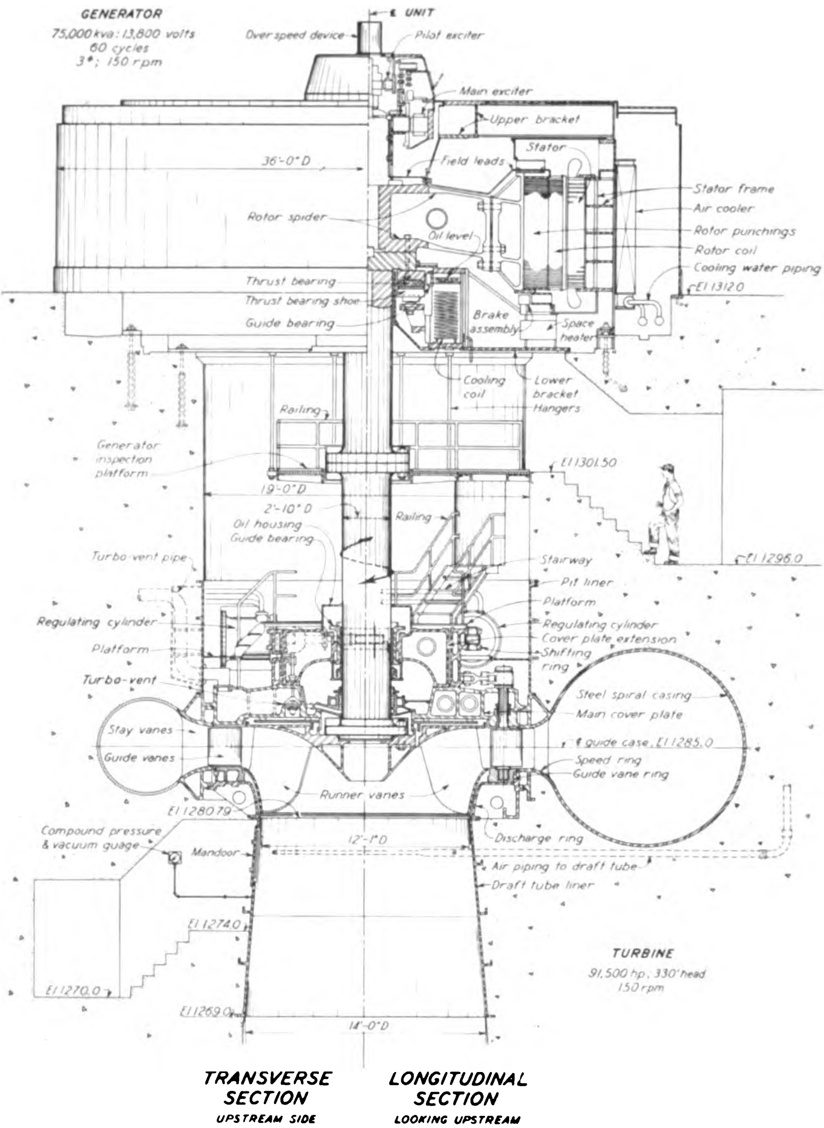


FIGURE 107.—*Fontana—turbine and generator sections.*

into sections in the manufacturer's shops in order to minimize the number of field welds required. The completed spiral cases were hydrostatically tested at a pressure of 175 percent of the design pressure.

The cast-steel runner has 15 buckets, and the water to the runner is controlled by 20 wicket gates. The turbine shaft is guided by an oil-lubricated, babbitt bearing above the head cover. An alternating-current oil pump supplies oil under pressure to the bearing under normal conditions and a direct-current pump comes into operation

automatically in case of failure of the alternating-current pump to supply sufficient oil to the bearing.

Soon after unit 1 was put into commercial operation it was discovered that the unit was noisy and unstable at about 50 percent gate opening under conditions of high head. The noise in the draft tube was described as "sounding like a heavy concrete mixer" and was accompanied by head cover pressure surges and power swings. Introduction of compressed air through the head cover alleviated the noise and vibration to some extent.

In an attempt to provide a more permanent remedy for this condition four vertical, V-shaped fins were installed in the draft tube of unit 1 approximately 18 inches below the runner. The fins are made of plate steel and are welded to the draft tube liner. Each has a 2-inch-diameter hole on the right side near the top and is vented to atmosphere through an embedded pipe installed during erection of the units. Since the fins are vented to atmosphere compressed air cannot be utilized in conjunction therewith.

While the fins do not completely stop the noise and power surges they do have a decidedly beneficial effect on the operation of the units. The fins have already been installed on units 1 and 3 and will be installed on unit 2 when an outage occurs.

A view of the Francis runner for unit 3 is shown in figure 108.

Governors

A single cabinet-actuator-type governor manufactured by the Allis-Chalmers Manufacturing Co. is provided for each unit. Each governor is complete with governor head, sump tank, pressure tank, oil pump, potential transformer for driving the governor head, and the necessary auxiliaries for remote control of the turbine from the control room.

The oil pumps each have a capacity of 135 gallons per minute at 300 pounds per square inch and are driven by a 40-horsepower motor. The sump tanks are located in the bottom portion of the actuator cabinets. The pressure tanks are located near the actuator, and each has a volume of 146 cubic feet. The pressure systems of all three units are interconnected so that any governor may be oper-

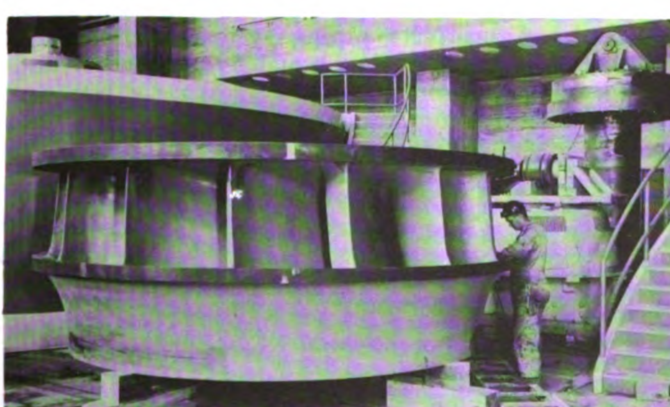


FIGURE 108.—*Fontana unit 3 Francis turbine runner.*

ated from the oil pump of one of the other governors in case of a pump failure.

With the addition of unit 3, facilities necessary for remote control of all three turbines from the electrical control room were installed.

A view of the governor cabinets at units 1 and 2 is shown in figure 109.

Generators

The three generators, manufactured by the Westinghouse Electric Corp., are the vertical shaft type, totally enclosed and cooled by forced-air circulation through water-cooled heat exchangers within the housing. Each generator has a rating of 75,000 kilovolt-amperes, 67,500 kilowatts, 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and operates at 150 revolutions per minute. The rotor is designed for a maximum runaway speed of 300 revolutions per minute.

Eight combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system and is automatically controlled. Oil pressure at 1,820 pounds per square inch for jacking is applied by means of a portable hand-operated oil pump.

The combination Kingsbury type thrust and segmental guide bearing is located below the rotor. The bearing is immersed in oil, which is cooled by water coolers located in the oil reservoir.

Fire protection is provided by a carbon-dioxide fire-extinguishing system, discharging through nozzles located in ring headers above the rotor. Sections of the generator are shown in figure 107.

Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are in the powerhouse equipment bay on the elevation 1296 floor. The oil storage facilities in the lubricating oil storage room consist of 1 clean-oil and 1 dirty-oil tank, each of 3,500-gallon capacity. One clean-oil and one dirty-oil pump, each of 30-gallon-per-minute capacity and a purifier of 350-gallon-per hour capacity are located in the oil purification room to service the lubricating oil. A complete piping system supplies and returns lubricating oil to the generator bearings, governors, and turbine

FIGURE 109.—*Fontana units 1 and 2 governor cabinets.*

bearings. The system is designed to prevent the mixing of clean and dirty oil, and flexibility of operation permits ten different pumping and purifying operations.

The insulating oil storage tanks, pumps, and purification equipment are also in the equipment bay on the same floor. The insulating oil storage facilities consist of 2 dirty transformer oil tanks, each of 5,190-gallon capacity, 1 dirty circuit breaker oil tank of 6,820-gallon capacity, and 1 clean insulating oil tank of 6,820-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 100-gallon-per-minute capacity. The insulating oil purifier has a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press. The pumps and purifier are located in the oil purification room. A complete piping system supplies and returns insulating oil to valve boxes near the electrical equipment in the switchyard, where connections are made with flexible hose to the drain and fill valves. The system is arranged to permit 10 different pumping and purifying operations.

A sluice-gates oil pressure system is provided for operation of the main spillway sluice gates and for the low level outlet emergency slide gate. At the main spillway two oil pumps (one intended for standby service) rated at 20 gallons per minute at 1,200 pounds per square inch and a 330-gallon-capacity storage tank are provided in the pump chamber. A complete piping system is provided for operation of the emergency and the service gates of each of the six sluiceways. A similar oil pressure system, except serviced by one oil pump, is furnished for operation of the low level outlet emergency gate.

Compressed air systems

Two stationary, single-stage, double-acting air compressors are provided in the CO_2 and air compressor room in the powerhouse equipment bay. One compressor is rated at 105 cubic feet per minute with a discharge pressure of 100 pounds per square inch and normally supplies the station compressed air requirements. The other compressor has a capacity of about 300 cubic feet per minute with a discharge pressure of 100 pounds per square inch and is set to cut in on a pressure drop below 90 pounds per square inch in the station air system. The system includes water-cooled aftercoolers, a 200-cubic-foot air receiver, and control equipment for automatic operation. A complete piping system, with service outlets, distributes compressed air throughout the powerhouse, to the generator brakes, and to the powerhouse deck.

The water level in the draft tubes may be depressed below the turbine runner for operation of the unit as a synchronous condenser by manually admitting compressed air from the station air system into the draft tube through the turbine head cover. Under normal tailwater conditions draft tube evacuation is not necessary.

A portable, air-cooled, electric-motor-driven air compressor, having a capacity of 105 cubic feet per minute and a discharge pressure of 100 pounds per square inch, is available for general service where required.

Compressed air for the governor system is supplied by a stationary, 2-stage, air-cooled, electric-motor-driven compressor with a capacity of 8 cubic feet per minute at a discharge pressure of 300

pounds per square inch. A separate piping system supplies 300-pound-per-square-inch air to the governor pressure tanks.

Raw water system

The raw water system provides water for unit cooling and lubrication, station services, fire protection, and other miscellaneous uses. Each generating unit has an intake from the penstock from which water flows by gravity to a manifold, passes through either of two rotary multiple-basket strainers to a second manifold, and then branches to supply three separate systems.

One raw water branch line supplies the unwatering and station drainage eductors at headwater pressure (maximum of 182 pounds per square inch).

A separate raw water system is supplied at a reduced pressure of 80 pounds per square inch from a pressure regulation station at the manifold for fire and service requirements. This system supplies the cooling coils of the air-conditioning systems located in the powerhouse and in the switchyard main leads tunnel. The system also supplies cooling water at a reduced pressure of 20 pounds per square inch to the gas-electric generator set, and at a reduced pressure of 40 pounds per square inch to the station air compressor and aftercooler. Lawn sprinklers near the switchyard are supplied from the fire main.

The third raw water system is supplied at a reduced pressure of 40 pounds per square inch from a pressure regulating station at the manifold for turbine and generator requirements. These include cooling water for the generator air coolers, generator bearing oil cooling coils, turbine bearing oil coolers, and lubricating water for the turbine seal rings and stuffing box.

The flow of water through the generator air coolers is automatically controlled by a motor-operated, thermostatically controlled proportioning valve which is set to maintain a proper constant temperature in the generator air housing. A motor-operated gate valve is provided in each of the three unit cooling and lubricating water supply lines at each unit for manual remote control from the control room.

The raw water system for unit cooling and lubrication has a series of alarm circuits operated by flowmeters to indicate low flows. The flowmeters in the turbine water supply line and in the cooling water supply to the generator bearing cooling coils have an additional contact to shut down or prevent starting the unit on low flow.

Treated water system

All treated water for the powerhouse is supplied from the Fontana Village filter plant which is operated by Government Services, Inc. The filter plant, which is located on the left bank downstream from the powerhouse, is a conventional type consisting of a coke tray aerator, chlorine contact tank, two 350-gallon-per-minute rapid sand gravity filters, a mixing chamber, a coagulation basin, chemical feeders, two chlorinators, a 48,650-gallon clearwell, one 3,000-gallon-per-minute backwash pump, two service pumps (one of 350-gallon-per-minute capacity and the other of 450-gallon-per-minute capacity), and a 21,000-gallon elevated storage tank.

Raw water is obtained from the forebay through one of 10 intakes at different elevations in the upstream face of the dam. The raw

water flows by gravity to the aerators and filter plant. The two high-head service pumps deliver treated water from the clearwell into the main to the 21,000-gallon storage tank which serves the sanitary fixtures in the powerhouse. Two booster pumping stations obtain water from the filter plant treated water storage tank and supply the village and construction camp area distribution systems and storage tanks for fire protection and sanitary service. The visitors' building obtains treated water from the mains in the construction camp area.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 1,350-gallon steel septic tank located at elevation 1296 between units 1 and 2. Under normal conditions of tailwater, the effluent from the tank drains directly to tailwater by gravity through an outlet in the draft tube pier. When tailwater rises above elevation 1294, the effluent from the tank is diverted to the station sump from which it will automatically be discharged to tailwater.

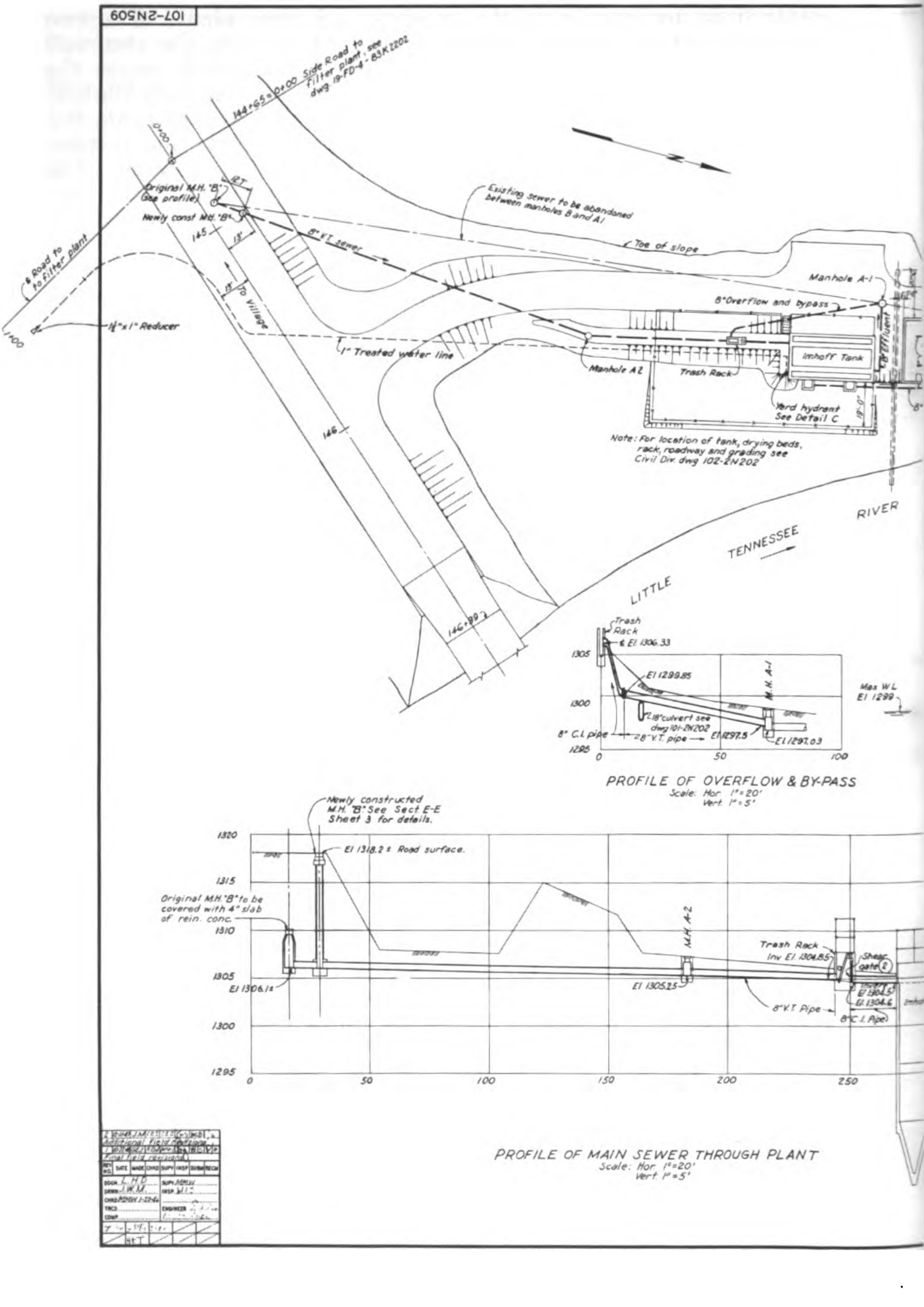
The waste from the Bee Cove toilet building, which is located near the boat harbor, discharges into a 6-inch sewer which connects to an 8-inch sewer in the construction camp area. The outfall sewer is built of 8-inch, mechanical-joint, cast-iron pipe and is about 1,700 feet long. The outlet discharges into the Little Tennessee River below the powerhouse through a concrete end wall.

The waste from the toilet facilities in the visitors' building at the east end of the dam discharges into a 5,700-gallon concrete septic tank located between the building and the main spillway. The effluent from the tank is disposed of through an open-jointed, 8-inch cast-iron pipe laid in the top of the rock fill on the downstream face of the dam.

All buildings in the village area are connected to the village sewerage system. The main sewers are of 8-inch concrete sewer pipe with a few short laterals of 6-inch concrete pipe. Standard manholes are installed at each change in grade or alignment. The outfall sewer is about 5,850 feet long and is built of 8-inch concrete pipe except for a few places on a trestle or filled ground where it is made of 8-inch, mechanical-joint, cast-iron pipe.

When the village was leased by the Government Services, Inc., for operation as a resort, the discharge of untreated sewage into the river was no longer allowable, and a sewage-treatment plant was constructed. The design chosen consists of a trashrack, an Imhoff tank, and sludge-drying beds. The Imhoff tank was designed to provide a 2-hour retention period in the settling chamber for a future flow of 150,000 gallons per day. The digestion chamber has a capacity of 2 cubic feet per capita based on an assumed future equivalent population of 1,500. On the same basis, the sludge-drying beds have a capacity of 1 square foot of surface area per capita.

All flow through the plant is by gravity, including the discharge of sludge to the drying beds. The effluent from the tank and sludge-drying beds discharges into the Little Tennessee River. The outlet is held securely in place by a concrete end wall and further protected by rock fill around the wall. A complete description of this treatment plant is given in chapter 12, "Sanitary Systems," and details are shown in plates 2, 3, and 4.


107-2N509
144+65=0+00 Side Road to filter plant, see dwg 19-FD-4-83K2202
Original M.H. "B" (See profile)
Newly const MH. "B"
℄ Road to to Filter plant
1½"x1" Reducer
8" V.T. sewer
To Village
1" Treated water line
Existing sewer to be abandoned between manholes B and A1
Toe of slope
Manhole A-1
8" Overflow and bypass
Imhoff Tank
8" Effluent
Manhole A2
Trash Rack
Yard hydrant See Detail C
Note: For location of tank, drying beds, rack, roadway and grading see Civil Div. dwg 102-2N202
146
146+89
LITTLE TENNESSEE RIVER
Trash Rack
℄ El. 1306.33
El 1299.85
M.H. A-1
2-18" culvert see dwg 101-2N202
8" C.I. pipe
8" V.T. pipe
El 1297.5
El 1297.03
Max W.L. El 1299
PROFILE OF OVERFLOW & BY-PASS
Scale: Hor. 1"=20' Vert. 1"=5'
Newly constructed M.H. "B" See Sect. E-E Sheet 3 for details.
El 1318.2± Road surface.
Original M.H. "B" to be covered with 4" slab of rein. conc.
El 1306.1±
M.H. A-2
El 1305.25
Trash Rack Inv El. 1304.85
Shear gate
El 1304.5
El 1304.6
8" V.T. Pipe
8" C.I. Pipe
PROFILE OF MAIN SEWER THROUGH PLANT
Scale: Hor. 1"=20' Vert. 1"=5'

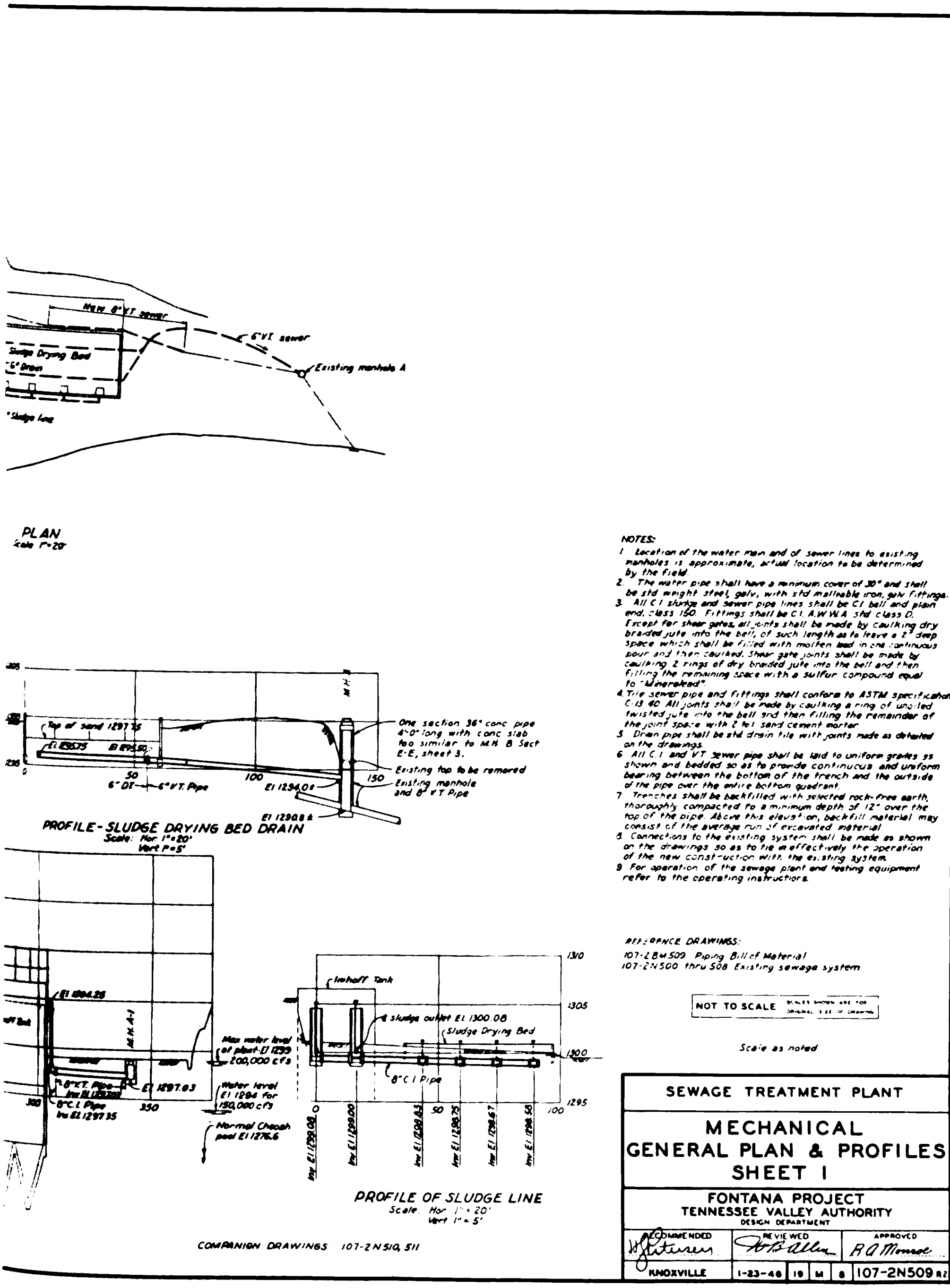
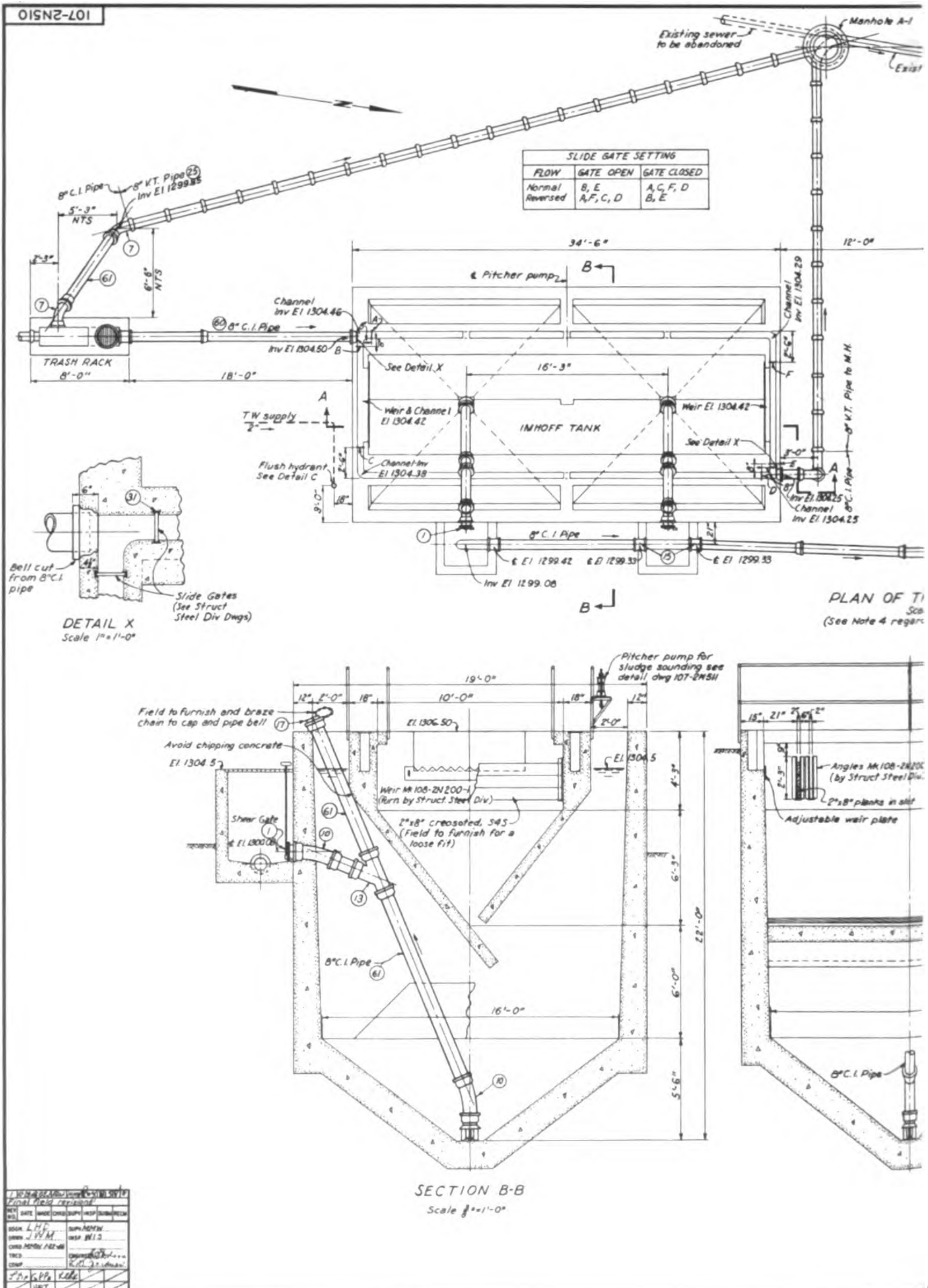
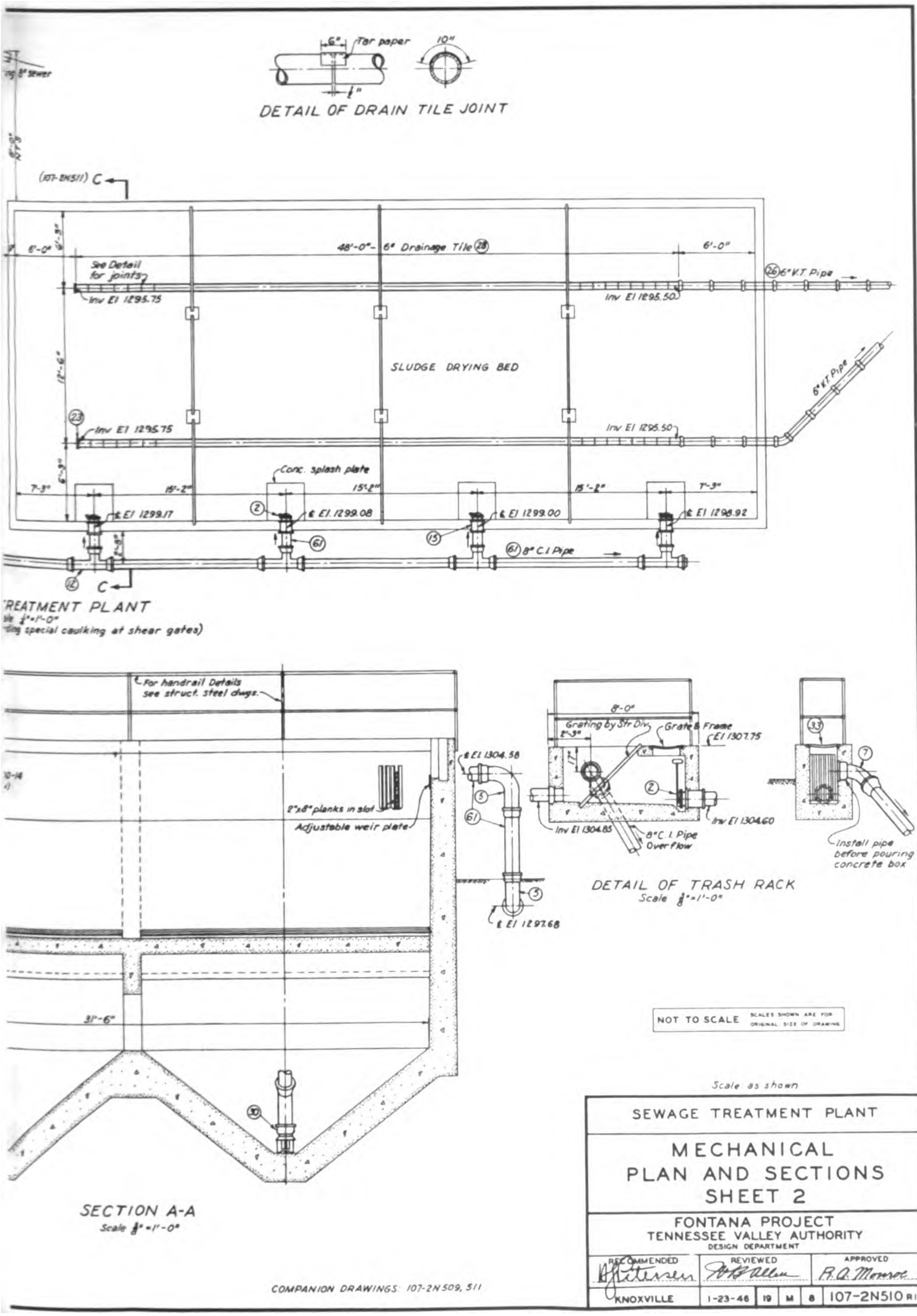

New 8" VT sewer
6" VT sewer
Sludge Drying Bed
6" Drain
Existing manhole A
Sludge line
PLAN
Scale 1"=20'
NOTES:
1 Location of the water main and of sewer lines to existing manholes is approximate, actual location to be determined by the field.
2. The water pipe shall have a minimum cover of 30" and shall be std weight steel, galv, with std malleable iron, galv fittings.
3. All C.I sludge and sewer pipe lines shall be C.I. bell and plain end, class 150. Fittings shall be C.I. A.W.W.A. std class D. Except for shear gates, all joints shall be made by caulking dry braided jute into the bell, of such length as to leave a 2" deep space which shall be filled with molten lead in one continuous pour and then caulked. Shear gate joints shall be made by caulking 2 rings of dry braided jute into the bell and then filling the remaining space with a sulfur compound equal to "Mineralead".
4. Tile sewer pipe and fittings shall conform to ASTM specification C-13-40. All joints shall be made by caulking a ring of unoiled twisted jute into the bell and then filling the remainder of the joint space with 2 to 1 sand cement mortar.
5 Drain pipe shall be std drain tile with joints made as detailed on the drawings.
6 All C.I and VT sewer pipe shall be laid to uniform grades as shown and bedded so as to provide continuous and uniform bearing between the bottom of the trench and the outside of the pipe over the entire bottom quadrant.
7 Trenches shall be backfilled with selected rock-free earth, thoroughly compacted to a minimum depth of 12" over the top of the pipe. Above this elevation, backfill material may consist of the average run of excavated material.
8 Connections to the existing system shall be made as shown on the drawings so as to tie in effectively the operation of the new construction with the existing system.
9 For operation of the sewage plant and testing equipment refer to the operating instructions.
Top of sand 1297.75
One section 36" conc pipe 4'-0" long with conc slab top similar to M.H. B Sect E-E, sheet 3.
Existing top to be removed
Existing manhole and 8" VT Pipe
6" DT
6" VT Pipe
El 1294.0
El 1290.8
PROFILE-SLUDGE DRYING BED DRAIN
Scale: Hor 1"=20'
Vert 1"=5'
REFERENCE DRAWINGS:
107-2BM509 Piping Bill of Material
107-2N500 thru 508 Existing sewage system
NOT TO SCALE
Scale as noted
Imhoff Tank
Sludge outlet El 1300.08
Sludge Drying Bed
Max water level of plant El 1299 200,000 cfs
Water level El 1294 for 150,000 cfs
Normal Cheoah pool El 1276.6
8" C I Pipe
8" VT Pipe
8" C.I. Pipe
Inv El 1297.35
El 1297.03
El 1304.25
Inv El 1299.08
Inv El 1299.00
Inv El 1298.83
Inv El 1298.75
Inv El 1298.67
Inv El 1298.50
PROFILE OF SLUDGE LINE
Scale Hor 1"=20'
Vert 1"=5'
COMPANION DRAWINGS 107-2N510, 511
SEWAGE TREATMENT PLANT
MECHANICAL
GENERAL PLAN & PROFILES
SHEET 1
FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
RECOMMENDED
REVIEWED
APPROVED
KNOXVILLE
1-23-46
107-2N509

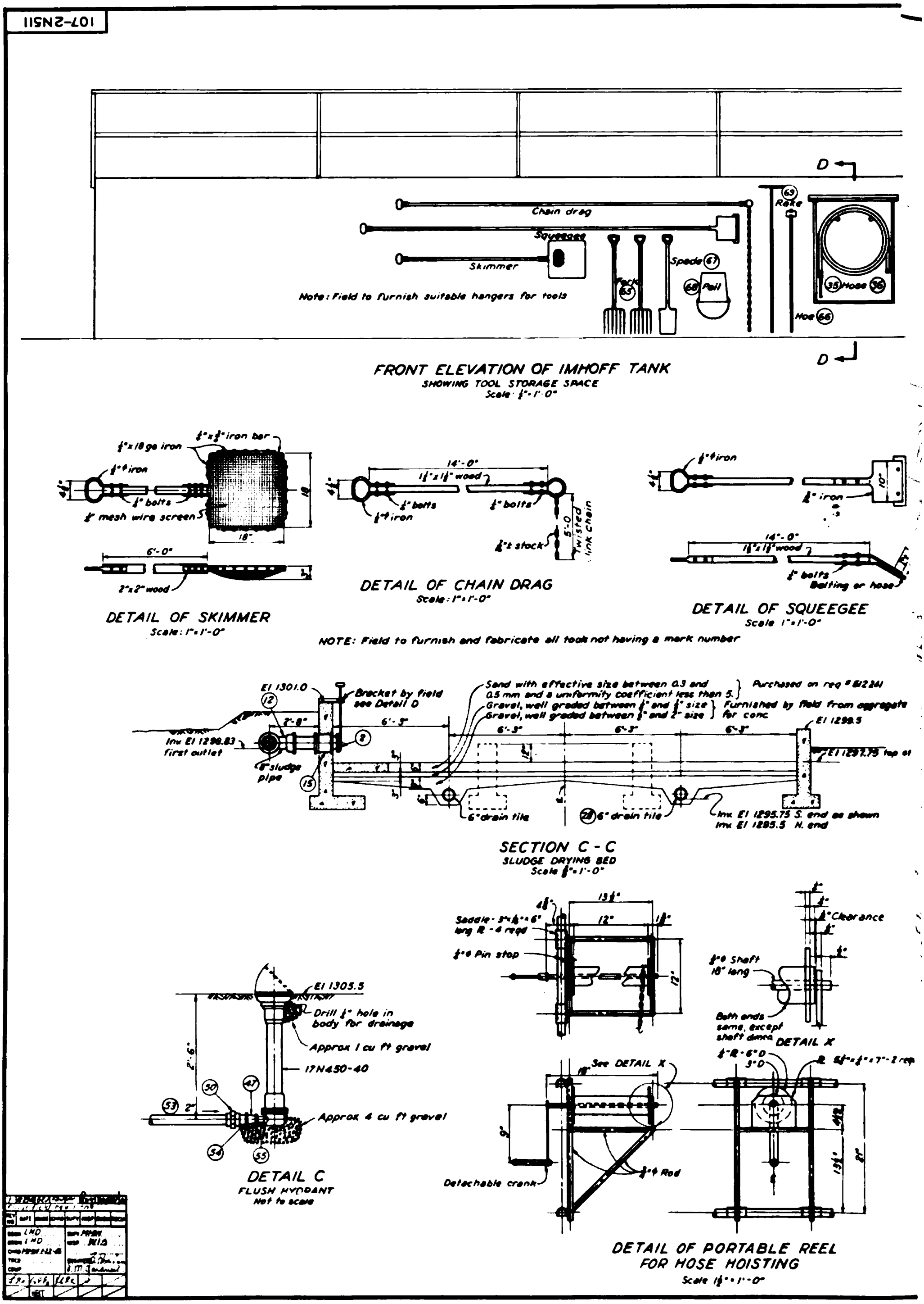
PLATE 2



107-2N510
Existing sewer to be abandoned
Manhole A-1
SLIDE GATE SETTING
FLOW
GATE OPEN
GATE CLOSED
Normal
Reversed
B, E
A, F, C, D
A, C, F, D
B, E
8" C.I. Pipe
8" V.T. Pipe
Inv El 1299.85
5'-3" NTS
6'-6" NTS
34'-6"
12'-0"
Pitcher pump
Channel Inv El 1304.46
8" C.I. Pipe
Inv El 1304.50
TRASH RACK
8'-0"
18'-0"
See Detail X
16'-3"
Channel Inv El 1304.29
T.W. supply 2"
Weir & Channel El 1304.42
IMHOFF TANK
Weir El 1304.42
See Detail X
8" V.T. Pipe to M.H.
Flush hydrant See Detail C
Channel Inv El 1304.38
Inv El 1304.25
Channel Inv El 1304.25
8" C.I. Pipe
8" C.I. Pipe
Inv El 1299.08
El 1299.42
El 1299.33
El 1299.33
PLAN OF T
(See Note 4 regar
Bell cut from 8" C.I. pipe
Slide Gates (See Struct Steel Div Dwgs)
DETAIL X
Scale 1" = 1'-0"
Pitcher pump for sludge sounding see detail dwg 107-2N511
19'-0"
12"
2'-0"
18"
10'-0"
18"
12"
Field to furnish and braze chain to cap and pipe bell
Avoid chipping concrete
El 1304.5
El 1306.50
El 1304.5
Weir Mk 108-2N200-1 (Furn by Struct Steel Div)
Shear Gate
El 1300.08
2"x8" creosoted, S4S (Field to furnish for a loose fit)
4'-3"
6'-3"
22'-0"
6'-0"
5'-6"
8" C.I. Pipe
16'-0"
SECTION B-B
Scale 3/8" = 1'-0"
Angles Mk 108-2N200 (by Struct Steel Div)
2"x8" planks in slot
Adjustable weir plate
8" C.I. Pipe
Final field revisions



6"
Tar paper
10"
¼"
DETAIL OF DRAIN TILE JOINT
(107-2N511) C
6'-0"
48'-0" - 6" Drainage Tile 28
6'-0"
See Detail for joints
Inv El 1295.75
Inv El 1295.50
26 6" V.T. Pipe
SLUDGE DRYING BED
12'-6"
6" V.T. Pipe
23
Inv El 1295.75
Inv El 1295.50
6'-3"
Conc. splash plate
7'-3"
15'-2"
15'-2"
15'-2"
7'-3"
℄ El 1299.17
2
℄ El 1299.08
℄ El 1299.00
℄ El 1298.92
61
15
61 8" C.I. Pipe
12
C
REATMENT PLANT
For handrail Details see struct. steel dwgs.
℄ El 1304.58
2"x8" planks in slot
Adjustable weir plate
5
61
5
℄ El 1297.68
8'-0"
Grating by Str Div.
Grate & Frame
El 1307.75
2'-3"
2
Inv El 1304.85
8" C.I. Pipe Over flow
Inv El 1304.60
33
7
Install pipe before pouring concrete box
DETAIL OF TRASH RACK
Scale ⅜"=1'-0"
NOT TO SCALE
SCALES SHOWN ARE FOR ORIGINAL SIZE OF DRAWING
31'-6"
30
SECTION A-A
Scale ⅜"=1'-0"
Scale as shown
SEWAGE TREATMENT PLANT
MECHANICAL
PLAN AND SECTIONS
SHEET 2
FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
RECOMMENDED
REVIEWED
APPROVED
R.A. Monroe
COMPANION DRAWINGS: 107-2N509, 511
KNOXVILLE
1-23-46
107-2N510 R1


107-2N511
Chain drag
Squeegee
Skimmer
Rake 69
Spade 67
Fork 65
68 Pail
35 Hose 36
Hoe 66
Note: Field to furnish suitable hangers for tools
D
FRONT ELEVATION OF IMHOFF TANK
SHOWING TOOL STORAGE SPACE
DETAIL OF SKIMMER
DETAIL OF CHAIN DRAG
DETAIL OF SQUEEGEE
NOTE: Field to furnish and fabricate all tools not having a mark number
El 1301.0
Bracket by field see Detail D
Inv El 1298.83 first outlet
6" sludge pipe
Sand with effective size between 0.3 and 0.5 mm and a uniformity coefficient less than 5.
Purchased on req # 612261
Furnished by field from aggregate for conc
6" drain tile
SECTION C - C
SLUDGE DRYING BED
El 1305.5
Approx 1 cu ft gravel
17N450-40
Approx 4 cu ft gravel
DETAIL C
FLUSH HYDRANT
Not to scale
See DETAIL X
Detachable crank
Clearance
DETAIL X
DETAIL OF PORTABLE REEL
FOR HOSE HOISTING

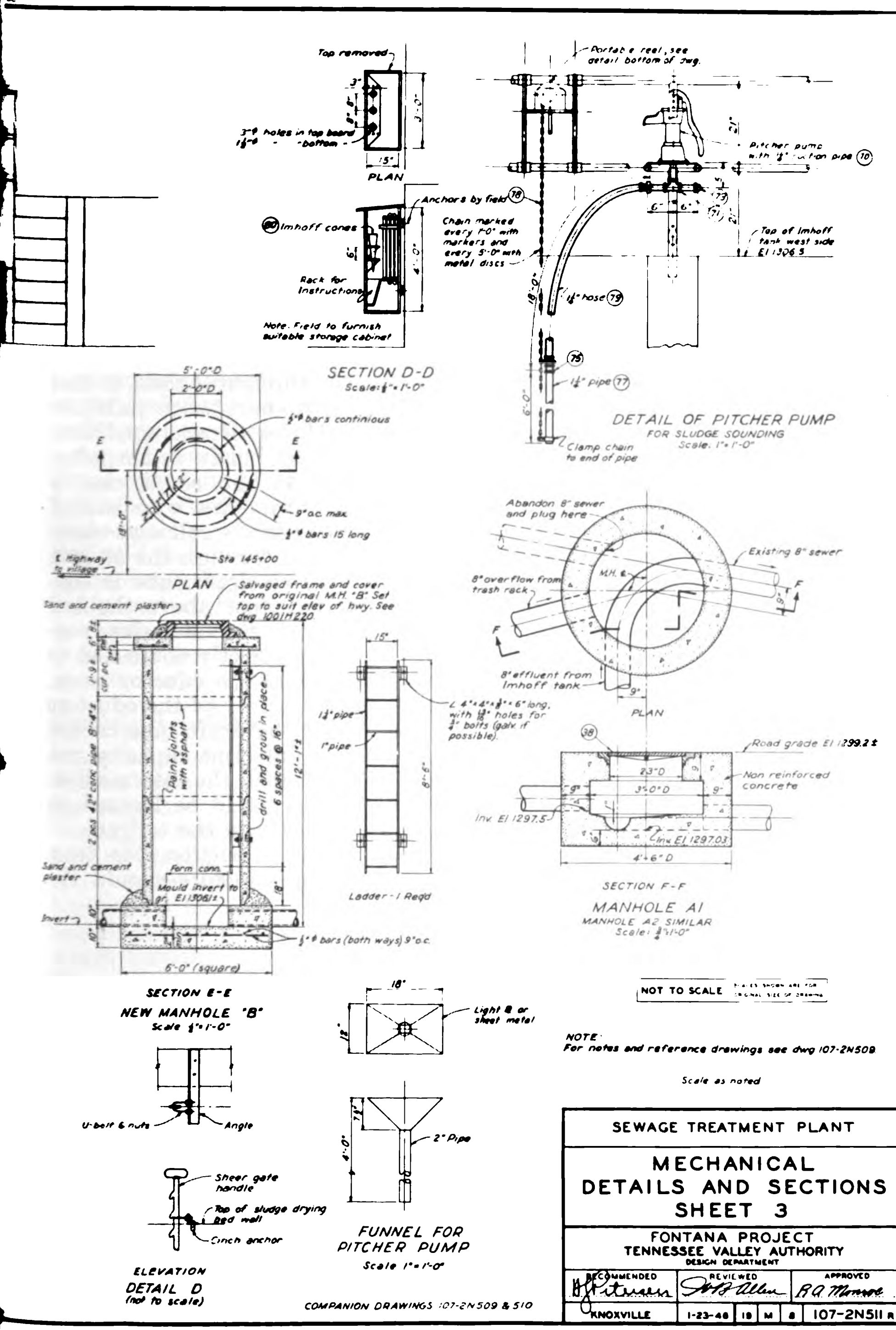

SECTION D-D
DETAIL OF PITCHER PUMP
FOR SLUDGE SOUNDING
Scale: 1" = 1'-0"
MANHOLE A1
MANHOLE A2 SIMILAR
SECTION F-F
SECTION E-E
NEW MANHOLE "B"
Ladder - 1 Reqd
FUNNEL FOR PITCHER PUMP
Scale 1" = 1'-0"
ELEVATION
DETAIL D
(not to scale)
NOT TO SCALE
NOTE
For notes and reference drawings see dwg 107-2N509
Scale as noted
COMPANION DRAWINGS 107-2N509 & 510
SEWAGE TREATMENT PLANT
MECHANICAL DETAILS AND SECTIONS SHEET 3
FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
RECOMMENDED
REVIEWED
APPROVED
KNOXVILLE
1-23-46
107-2N511 R1

PLATE 4

Drainage and unwatering

All powerhouse roof and deck drains and miscellaneous cooling and raw water lines discharge directly to tailwater. Numerous powerhouse drains above elevation 1282, including the septic tank effluent, normally discharge into the tailrace but are diverted to the station sump when tailwater rises above elevation 1294. Building and unit drainage from elevation 1282 and below drains directly into the station sump.

The station drainage sump is between units 1 and 2, adjacent to the eductor room. It has a capacity of approximately 9,365 gallons and is serviced by one 500-gallon-per-minute, deepwell, turbine-type pump and one 6-inch water jet eductor discharging directly to the tailrace. The 500-gallon-per-minute pump acts as a standby for excessive drainage flow into the sump.

An unwatering system for all draft tubes and scroll cases is used to permit inspection and repair of turbine runners when tailwater is above the bottom of the turbine runner. Under normal conditions the bottom of the runner is above tailwater and may be inspected without dewatering. Each intake conduit to the scroll case is equipped with a drain outlet and a 16-inch drain line with shutoff valve. When the head gate is closed the water in a scroll case comes to tailwater level through the wicket gates and through the 16-inch drain line emptying into the draft tube. Each draft tube is constructed with a drain outlet approximately 1 foot above the low point of the draft tube. A 14-inch pipe, with shutoff valve, connects the drain outlet to a manifold which is directly connected to the suction of two water jet eductors located in the eductor room.

If the draft tube gate leakage exceeds the capacity of the eductors and the need for inspection of the bottom of the draft tube cannot be satisfied by a diver, a portable pump of sufficient capacity can be temporarily installed in a 30-inch pump well in the intermediate pier of each draft tube. This portable pump would be located on the draft tube deck and would discharge directly to the tailrace.

Provision has been made for a possible future suction line from the station drainage sump to the unwatering eductors should the situation demand it.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is provided for protection of the generators, the gas-electric generator room, the oil storage rooms, and the oil purification room. The system is arranged for local manual or automatic remote control.

The carbon-dioxide system consists of three banks of 50-pound cylinders including an initial bank and a reserve bank, each of 14 cylinders, and a delayed bank of 10 cylinders. The initial bank is arranged for the simultaneous release of all 14 cylinders to any generator. The delayed discharge bank is arranged for intermittent discharge to maintain a sufficient concentration in the generator housing. The reserve bank is arranged with interconnecting piping and controls to function in any emergency the same as the initial bank for generator protection. Normally the reserve bank is used to automatically release groups of cylinders for protection of the

gas-electric generator room, the lubricating oil storage room, the insulating oil storage room, or the oil purification room.

Raw water at a reduced pressure of 80 pounds per square inch is supplied for general fire protection in the powerhouse and switchyard. Eight fire hose racks are provided throughout the building. Each outlet is equipped with a valve, 75 feet of fire hose on a rack, and a hose nozzle. The switchyard contains three 4-inch fire hydrants. Two fire hose carts, each complete with wrenches, reel, 100 feet of fire hose, and two nozzles, are conveniently located in the switchyard. Two fire protection equipment buildings are provided for storing the hose carts and portable carbon-dioxide fire-extinguishing equipment.

Service equipment

The machine shop, which is conventional size, is in a separate room in the equipment bay adjacent to the generator room. The shop includes equipment as listed in table 14, page 626.

An automatic pushbutton-controlled elevator is installed for the use of operating personnel and serves the three operating floor levels in the powerhouse. The elevator has a total lift of 34 feet and a live load capacity of 2,500 pounds at a speed of 60 feet per minute. Design data covering this machine are included in table 6, page 394.

The emergency auxiliary power generating unit, which is installed in the service bay at elevation 1296, has a 125-kilovolt-ampere, 0.8 power factor, 3-phase, 60-cycle, 480-volt generator with direct-connected exciter, driven by a 180-brake-horsepower, 6-cylinder gasoline engine operating at 1,200 revolutions per minute.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, telephone room, visitors' lobby, assembly room and offices of the powerhouse, and for the reception room and refreshment bar of the visitors' building. Cooling is provided for the generator leads tunnels to prevent overheating during warm weather. The remainder of the powerhouse and visitors' building is mechanically ventilated. Electric unit heaters or blower blast heater assemblies located throughout the buildings heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Heat exhausted from the generator leads and other electrical equipment may be recirculated to the powerhouse during cold weather to conserve heat. Portable electric heaters serve to supplement the permanently connected heaters as required.

The powerhouse air-conditioned spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of lake water through the cooling coils. The generator leads tunnel cooling coils are similarly supplied with cool lake water.

The visitors' building air-conditioned spaces are served by a combination heating, cooling, and ventilation system complete with fan, refrigerant compressor, air-cooled condenser, cooling coils, heating coils, humidifier, air filters, air distribution system, and controlling

FIGURE 110.—*Watauga powerhouse and control building.*

devices. Due to the large exterior glassed areas of the reception and refreshment bar rooms, a floor-embedded, hot-water, radiant heating system is installed. Electrically heated water is circulated through floor-embedded piping. A more complete description of this radiant heating system with illustrations is presented in chapter 14, "Heating, Ventilating, and Air Conditioning." Cooling and dehumidification are accomplished by the mechanical refrigeration plant.

The total capacities of the heating, ventilating, and air-conditioning systems are as follows:

Cubic feet per minute of air supplied and exhausted	371,180
Kilowatts of installed electric heating	791
Horsepower of refrigeration	30

WATAUGA

Watauga Dam is on the Watauga River at river mile 36.7 in eastern Tennessee and 2.7 miles upstream from Wilbur Dam. The project is a combined power and flood control type, contributing a generating capacity of 50,000 kilowatts to the system and providing a useful controlled storage volume of 627,200 acre-feet. Although the project was originally authorized in 1942, work was resumed in 1946 after construction had been deferred as a result of a War Production Board order. Authorization, construction, operation, and cost data are as follows:

Authorization	January 15, 1942
Construction started	February 16, 1942
Closure	December 1, 1948
Commercial operation:	
Unit 2	August 30, 1949
Unit 1	September 29, 1949
Cost of the 2-unit project, including switchyard	$32,335,243

The principal features of the Watauga project are a rock and rolled earth fill dam; an uncontrolled, morning-glory-type spillway discharging into a shaft and tunnel; a sluiceway controlled by two 96-inch Howell-Bunger valves which discharge into the spillway tunnel; a power intake supplying the 18- and 20-foot-diameter, 3,410-foot power tunnel; a differential-type underground surge chamber; an 11-foot-diameter butterfly valve in each of two steel penstocks; the 2-unit powerhouse; and, across the river from the powerhouse, a separate control building and switchyard (figs. 110, 111, and 112). The access road to the powerhouse approaches from downstream on the switchyard side and continues across the river on a bridge to the draft tube deck and powerhouse entrance.

The dam is about 900 feet long, 318 feet high, and 1,260 feet wide at the base. On the right bank, a 34-foot-diameter diversion tunnel is utilized for the discharge of a morning-glory spillway. The spillway has a 128-foot-diameter circular weir over which the water passes to a vertical, 34-foot-diameter, concrete-lined shaft and an elbow into a connection with the diversion tunnel. The tunnel now serves as a low level outlet or sluiceway which is equipped with an intake portal having a curved trashrack and an operating tower projecting above the lake surface. In the control section the former diversion tunnel has a concrete plug in which are two water passages.

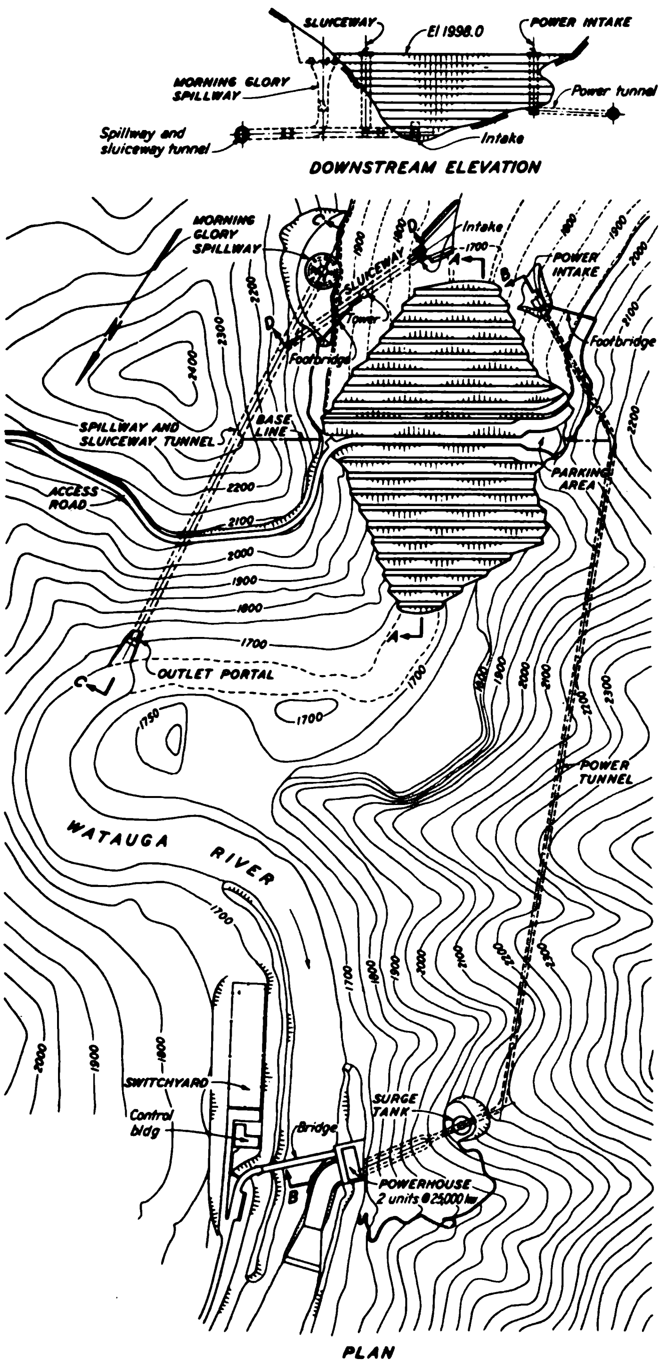
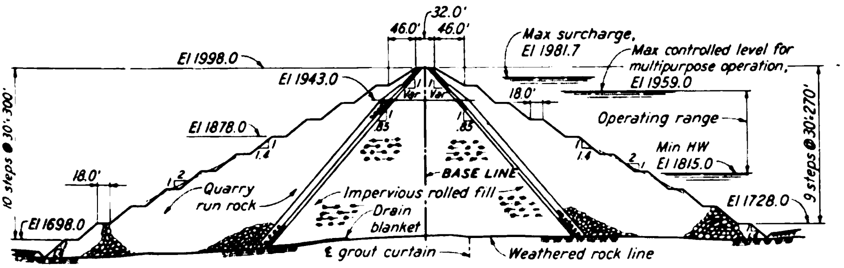
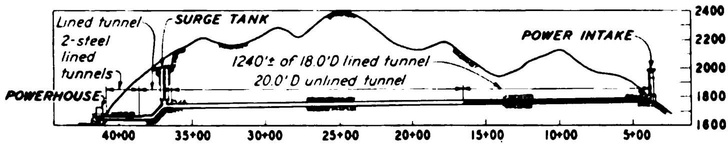


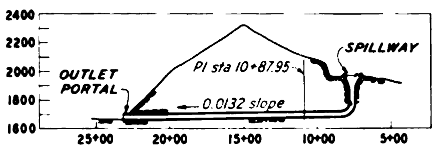
FIGURE 111.—*Watauga general*



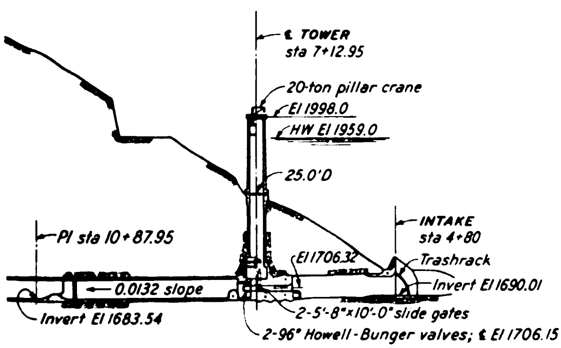
SECTION A - A



SECTION B - B



SECTION C - C



SECTION D - D

plan, elevation, and sections.

A 96-inch Howell-Bunger valve at the outlet of each passage normally controls the flow in the sluiceway with emergency closure of either passage secured by a 5-foot 8-inch by 10-foot hydraulically operated slide gate. The operating tower provides access to the valves and also furnishes the air intake required for the operation of the Howell-Bunger valves. The discharge from the outlet portal of the tunnel is dissipated in the river canyon.

On the left bank of the river channel a power tunnel extends about 3,700 feet through the mountain forming the left abutment of the dam. The intake structure is of reinforced concrete and consists of guides for a lift gate with a bracing wall and a platform. Space for the treated water filter plant is provided in the power intake tower above maximum headwater with multiple raw water intakes below. Figure 112 is a view of Watauga Dam from the upstream side showing the power tunnel intake tower in the foreground with sluiceway control tower and morning-glory spillway at right background.

The power tunnel develops about 35 feet of head between the dam and powerhouse. The tunnel consists of 18-foot lined and 20-foot unlined sections from the intake to the surge tank, an 18-foot-diameter concrete-lined section to a Y-branch from which two 11-foot-diameter power conduits, 257 feet long and lined with steel plate, extend to the two units in the powerhouse. The surge tank is the differential type and formed by excavation in the hillside above the powerhouse. At the inlet to the scroll case of each unit an 11-foot-diameter butterfly valve is installed.

A cross section of the powerhouse is shown in figure 113. The frame of the building consists of structural steel columns and girders with a rigid frame supporting the roof. The exterior walls are fluted aluminum sheets, backed with insulation and sheet steel. The service bay is at one end of the generator room. An electrical bay, consisting of two stories, is above the draft tubes, and the two main power transformers are mounted on the deck above the electrical bay. A single track was provided for the two transformers which requires both to be moved if the one farther from the entrance requires moving. This appeared to be the most economical arrangement.

The generator room is enclosed and served by an indoor crane. Figure 114 is a view of the generator room with unit 1 in the foreground. The face of the twin governor cabinet extends into the generator room with the governor pressure tanks located behind the cabinet in the electrical equipment room.

The switchyard and control building are across the Watauga River from the powerhouse. Compressed air, raw water, and treated water service lines extend across the powerhouse access bridge. Control equipment is provided in the Watauga control room for remote control of Watauga, South Holston, and Wilbur unit 4 generators.

Turbines

Two vertical Francis-type hydraulic turbines, manufactured by the Newport News Shipbuilding & Dry Dock Co., are direct-connected to the generators. The turbines are rated 34,500 horsepower at a net head of 216 feet and operate at a speed of 200 revolutions

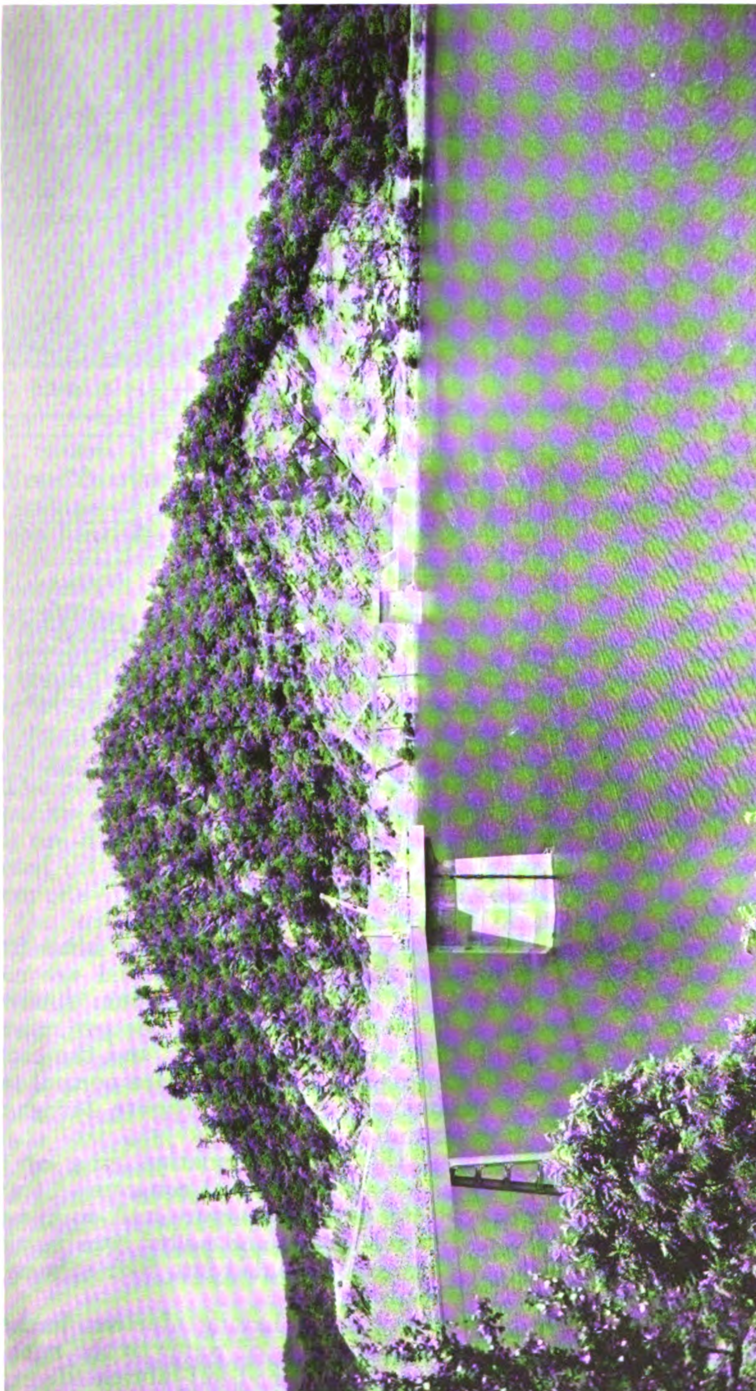


FIGURE 112.—*Watauga project—power intake tower in left center with sluiceway control tower and morning glory spillway just to right at center.*

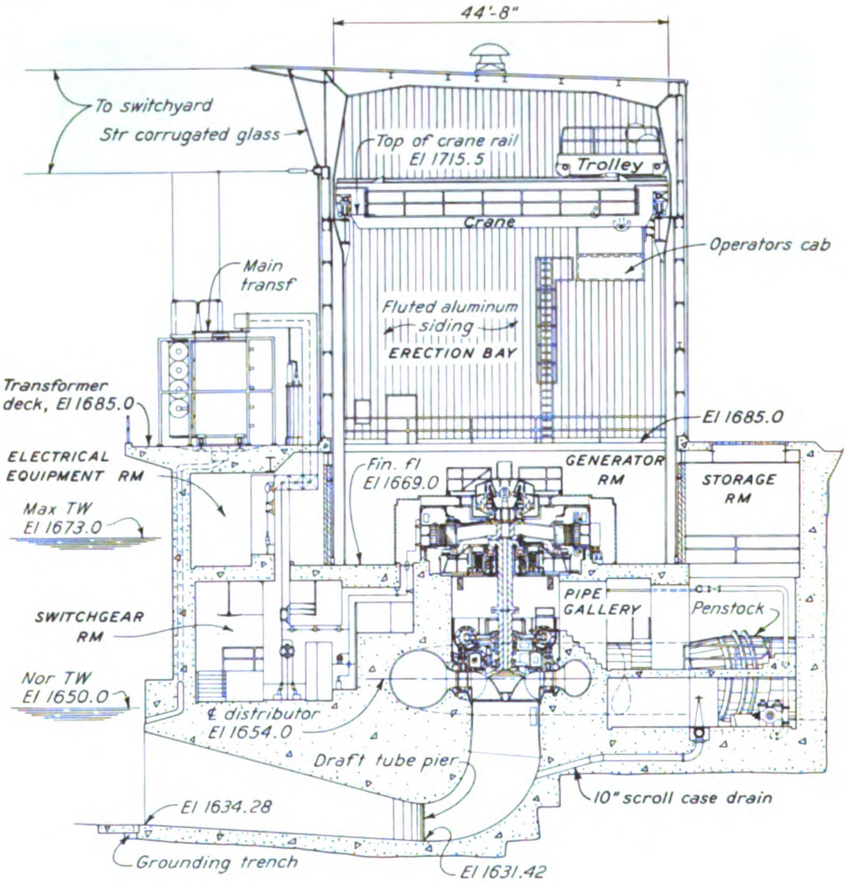


FIGURE 113.—*Watauga powerhouse cross section.*

per minute. They are designed to operate under any net head from a minimum of 165 feet to a maximum of 309 feet and are most efficient at a net head of about 275 feet. The maximum runaway speed for which each unit is designed is 395 revolutions per minute. At rated conditions the value of specific speed is 45, and the center line of the runner is located approximately 4 feet above normal tail-water elevation, giving a plant sigma of 0.135. Figure 115 shows sections of the turbine and generator.

A cast-steel stay ring forms the main foundation ring of the turbine, and the twelve stay vanes act as vertical columns to transmit to the foundations the weight of the structure and equipment above. The spiral case is plate-steel welded and bolted construction. The spiral case and stay ring were shop welded into four subassemblies and bolted together at the project.

The runner is a one piece steel casting having nineteen buckets. Eighteen steel wicket gates control the flow of water to the runner. The turbine shaft is guided by a babbitt-lined, oil-lubricated, gravity-flow bearing located above the head cover. An alternating-current oil pump is used to circulate the oil under normal conditions and

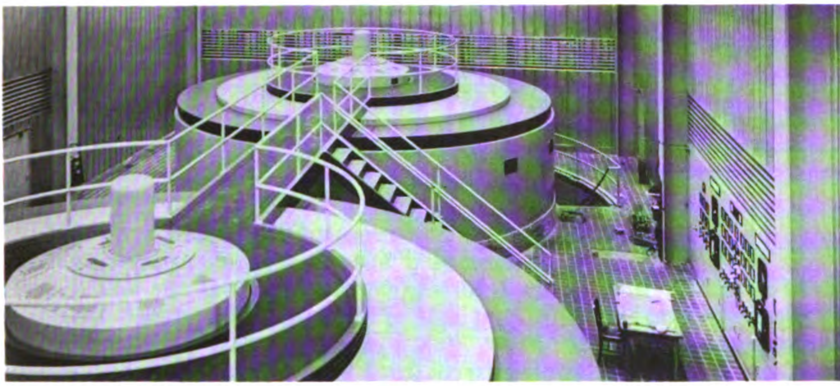


FIGURE 114.—*Watauga generator room.*

a direct-current oil pump comes into operation automatically in case of failure of the alternating-current pump to supply sufficient oil to the bearing.

Governors

The governors are the twin cabinet-actuator type manufactured by the Woodward Governor Co. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the turbine from the control building.

The oil pumps are of the herringbone gear type, each with a capacity of 100 gallons per minute at 300 pounds per square inch, and are driven by 35-horsepower motors. The units have interconnected oil pressure systems so that both governors may be operated from one oil pump. The combined sump tank is located in the base of the actuator cabinet. The pressure tanks are located directly behind the actuator cabinet, and each has a volume of 88 cubic feet.

Butterfly valves

One 132-inch butterfly valve of split body design is located in each penstock immediately upstream of the turbine spiral case. The valves were designed and manufactured by the Joshua Hendy Iron Works, Sunnyvale, Calif. Each valve is equipped with a 35-horsepower, 250-volt, direct-current motor and is set for a closing time of 360 seconds. The clear area with the valve completely open is 78.8 percent of the total cross sectional area. The guaranteed maximum leakage at the maximum head of 325 feet is 13 gallons per minute. Specifications for these valves are included in appendix A and plate 5 shows the installed location at the scroll inlet.

Generators

The two generators shown in figure 114 were manufactured by the Westinghouse Electric Corp. They are the vertical shaft type, totally enclosed, and are cooled by forced-air circulation through six water-cooled heat exchangers within the housing. Each gener-

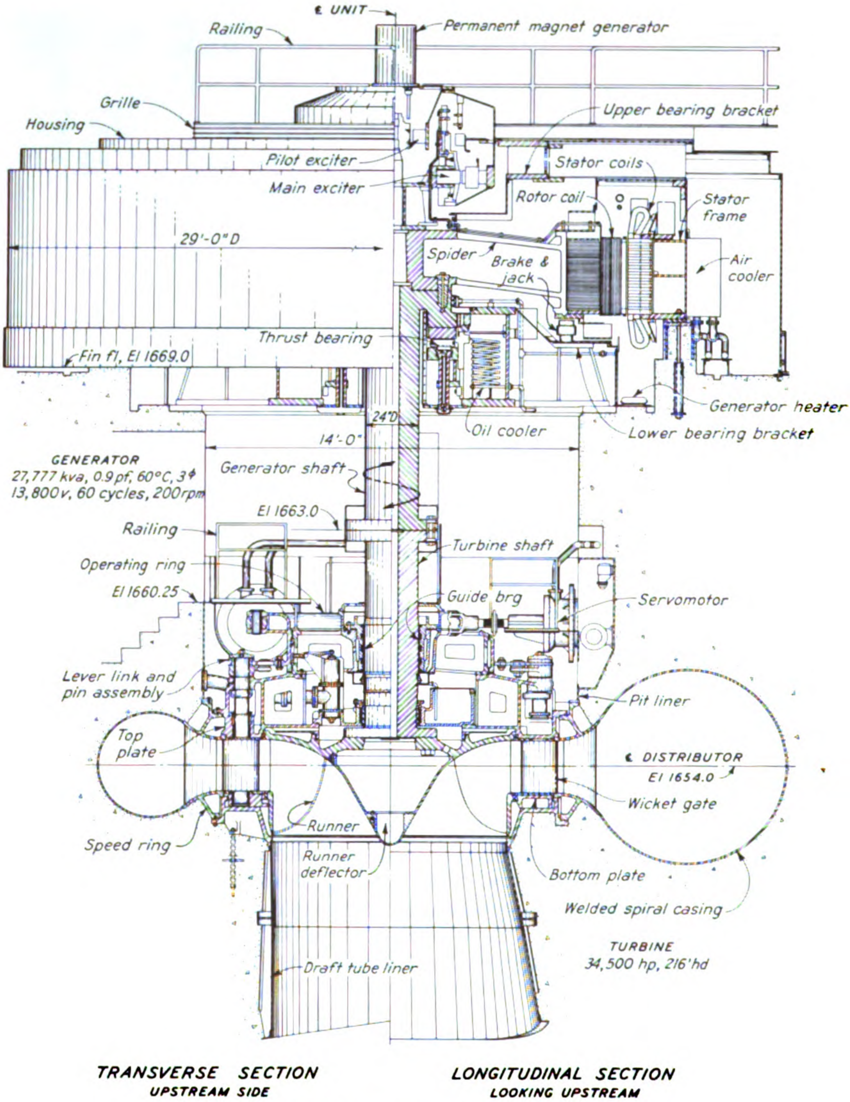


FIGURE 115.—*Watauga—turbine-generator sections.*

ator has a normal rating of 27,778 kilovolt-amperes, 25,000 kilowatts, 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and operates at 200 revolutions per minute. The rotor is designed for a maximum runaway speed of 395 revolutions per minute.

Six combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system and is automatically controlled. Oil pressure at 1,800 pounds per square inch for jacking is applied by means of a portable hand-operated oil pump.

The combination Kingsbury type thrust and segmental guide bearing is below the rotor. The bearing is immersed in oil, which is cooled by water coolers located in the oil reservoir.

Generator fire protection is provided by an automatic carbon-dioxide fire-extinguishing system, discharging through nozzles located in ring headers above the rotor.

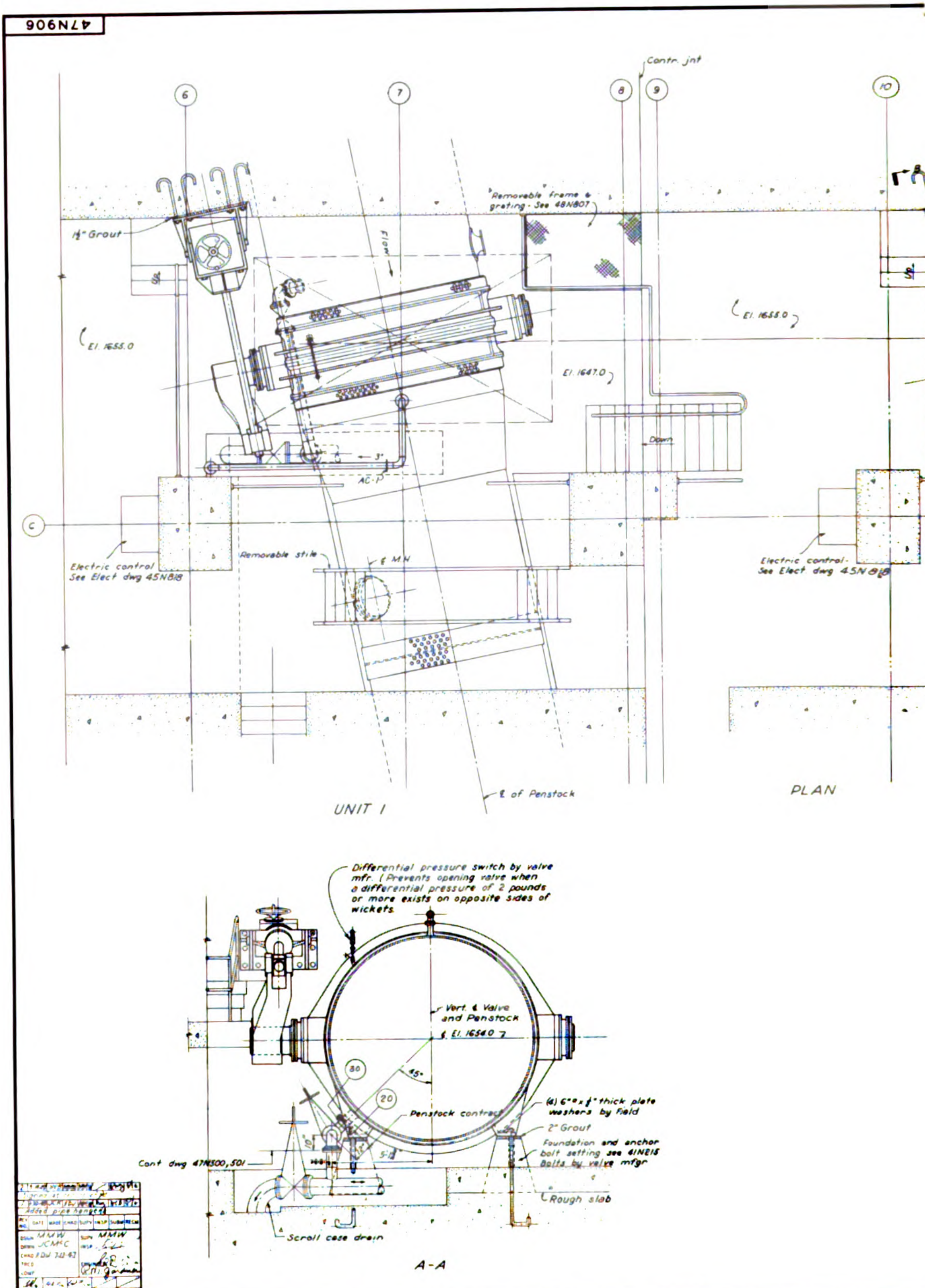
Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are in the basement of the powerhouse service bay. The storage facilities consist of 1 clean- and 1 dirty-oil tank, each of 3,210-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 37-gallon-per-minute capacity; and a stationary purifier of 350-gallon-per-hour capacity is provided. A complete piping system supplies and returns lubricating oil to the generator guide and thrust bearings, turbine guide bearings, and governor oil systems. The turbine bearing oil circulating system includes an alternating-current pump, with a direct-current pump for emergency service.

Two separate insulating oil systems are installed, both serviced by one portable purifier having a capacity of 600 gallons per hour without the filter press or 900 gallons per hour with the press. The powerhouse insulating oil system, complete with pumping and storage equipment and connections for attaching the portable purifier, services the oil-insulated electrical equipment on the transformer deck. One clean- and one dirty-oil pump, both in the basement of the powerhouse service bay and each having a capacity of 120 gallons per minute, are furnished in addition to 1 clean and 1 dirty transformer oil storage tank, each of 7,350-gallon capacity, located underground in the fill beside the powerhouse service bay. A complete piping system with valve boxes near the electrical equipment for hose connections is provided for the various pumping and purifying operations.

The oil purification building in the switchyard contains the switchyard insulating oil pumping equipment and space for the portable insulating oil purifier. One clean-oil and one dirty-oil pump, each of 115-gallon-per-minute capacity, are provided. Storage facilities, located adjacent to the purification building, include one 7,050-gallon dirty circuit breaker oil tank, one 10,620-gallon clean insulating oil tank, and space for a future dirty transformer oil tank. A complete piping system with valve boxes near the electrical equipment in the switchyard is provided for the various pumping and purifying operations.

The two sluice gates, which serve as emergency gates for the Howell-Bunger valves in the sluiceway, are raised and lowered by means of hydraulic cylinders above the bonnet of each valve. Oil pressure for the operation of the cylinders is supplied by a 20-gallon-per-minute pump with a discharge pressure of 1,200 pounds per square inch. The pump, together with a 330-gallon oil storage tank, is in the sluiceway tower on the elevation 1750.65 landing. A complete piping system conveys the oil to and from the cylinders.


47N906
Contr. jnt
6
7
8
9
10
1½" Grout
Removable frame & grating - See 48N807
Flow
El. 1655.0
El. 1655.0
El. 1647.0
Down
AC-P
C
Electric control See Elect dwg 45N818
Removable stile
℄ M.H.
Electric control- See Elect. dwg 45N818
UNIT I
℄ of Penstock
PLAN
Differential pressure switch by valve mfr. (Prevents opening valve when a differential pressure of 2 pounds or more exists on opposite sides of wickets.
Vert. ℄ Valve and Penstock
℄ El. 1654.0
45°
80
20
Penstock contract
(4) 6"□ x ⅝" thick plate washers by field
2" Grout
Foundation and anchor bolt setting see 41N815 Bolts by valve mfgr
Cont dwg 47N500, 501
Rough slab
Scroll case drain
A-A

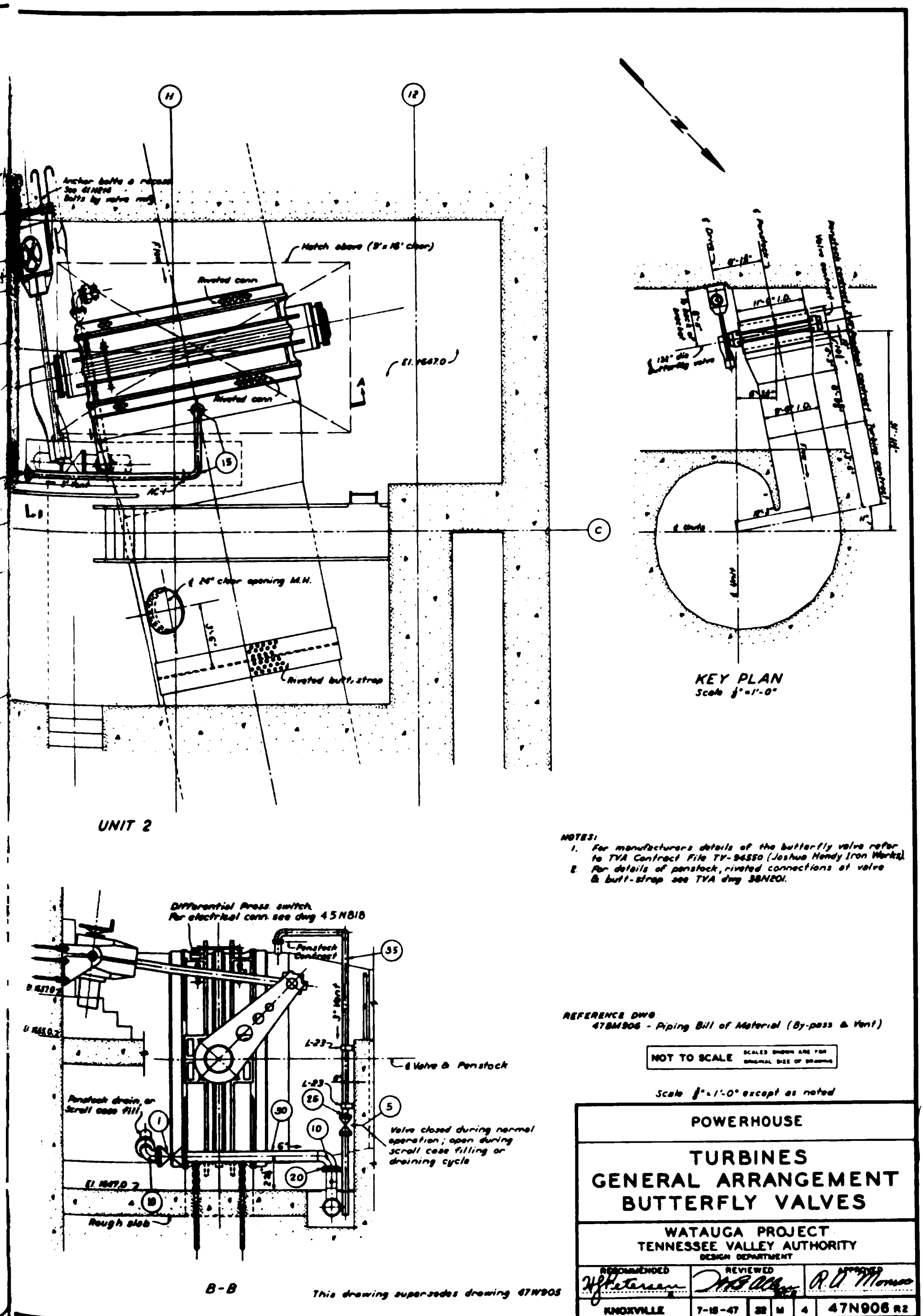

UNIT 2
KEY PLAN
Hatch above (8'x 16' clear)
Riveted conn.
El. 1647.0
20" clear opening M.H.
Riveted butt-strap
B-B
Differential Press. switch
For electrical conn. see dwg 45N818
Penstock drain, or Scroll case fill
Valve closed during normal operation; open during scroll case filling or draining cycle
El. 1647.0
Rough slab
NOTES:
1. For manufacturers details of the butterfly valve refer to TVA Contract File TV-94550 (Joshua Hendy Iron Works)
2. For details of penstock, riveted connections at valve & butt-strap see TVA dwg 38N201.
REFERENCE DWG
47BM906 - Piping Bill of Material (By-pass & Vent)
NOT TO SCALE
This drawing supersedes drawing 47W905
POWERHOUSE
TURBINES
GENERAL ARRANGEMENT
BUTTERFLY VALVES
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
RECOMMENDED
REVIEWED
APPROVED
KNOXVILLE
7-18-47
47N906 R2

PLATE 5

Compressed air systems

A complete piping system distributes compressed air throughout the powerhouse to the generator brakes, service outlets, the pneumatic control board for operation of ventilating dampers, and for instrument control of the raw water pressure reducing stations. A 1½-inch supply line from the powerhouse air system extends across the bridge to the control building. It supplies the control building air distribution system, including service outlets, the pneumatic control boards for operation of ventilating dampers, and control instruments of the treated water pressure reducing valve. A stationary air-cooled, 2-stage, electric-motor-driven direct-connected air compressor is in the powerhouse service bay. The compressor has a capacity of 60 cubic feet per minute and discharge pressure of 100 pounds per square inch. The system includes a 50-cubic-foot air receiver and control equipment for automatic control.

A portable, air-cooled, single-stage, electric-motor-driven air compressor of 90-cubic-foot-per-minute capacity and 100-pound-per-square-inch discharge pressure is available for general service where required.

Compressed air for the governor system is supplied by a stationary, 2-stage, air-cooled, electric-motor-driven compressor with a capacity of 8.3 cubic feet per minute and a discharge pressure of 300 pounds per square inch. The compressor is complete with receiver and controls for automatic operation.

Raw water system

Raw water from the reservoir is used for fire protection, service outlets, unit cooling, and lubricating. An intake in the penstock of each unit supplies the 10-inch raw water supply header through either of two twin strainers. The water flows by gravity to furnish the various raw water requirements of the station.

The station drainage sump eductor is supplied at unreduced pressure (maximum of 145 pounds per square inch) from the raw water header. The flow to the eductor is throttled seasonally as the reservoir level varies. Also supplied at full headwater pressure is the transformer water-spray fire-protection system on the transformer deck.

A complete pressure regulating station reduces the raw water pressure at the manifold to 60 pounds per square inch for use in the fire and service system. A 6-inch raw water supply line from this system extends from the powerhouse across the bridge to the control building for use in the air-conditioning equipment condensers, for fire protection, and for floor flushing through service outlets. Lawn sprinklers adjacent to the control building and fire hydrants in the switchyard and control building area obtain their supply from this system.

A second pressure regulating station, consisting of two 4-inch reducing valves operating in echelon with air-operated pressure controllers, is installed to reduce the raw water pressure to 40 pounds per square inch for unit cooling and lubricating. The generator air coolers and the generator thrust and guide bearing oil coolers obtain cooling water from these valves. Also supplied are the turbine water requirements for the turbine bearing oil coolers, the packing box, and the runner seal rings.

Each pressure regulating station is equipped with a globe valve bypass and appropriate pressure relief valves. A motor-operated gate valve is provided for remote control of flow to the units. The flow through the generator air coolers is automatically controlled by a motor-operated proportioning valve equipped with a temperature controller to maintain a proper air temperature in the generator air housing. An antisyphon arrangement prevents draining of the air coolers when the water supply is stopped.

The raw water supply lines of each unit to the turbine, to the generator air coolers, and to the generator bearing oil coolers are equipped with flowmeters and a series of alarm circuits to indicate low flow. An additional electrical contact shuts down or prevents starting the unit on low flow to the generator air coolers and to the turbine. An additional contact in the generator bearing water flowmeter prevents starting the unit at low flow.

Treated water system

Treated water for drinking and sanitary use in the powerhouse, control building, maintenance building, visitors' building, and picnic area is supplied from the water-treatment plant in the power intake tower. The only treatment given to the water is chlorination with provision for stabilization by some alkali or sodium hexametaphosphate. Three chemical feeders are provided for this purpose, one of which is a spare. Two 10-gallon-per-minute deepwell pumps supply the system from multiple-level raw water intakes from the reservoir. One pump serves as a standby. The treated water flows to a 1,655-gallon underground storage tank located at elevation 2200 (approximate) on the right bank. The chemical feeders and pumps are float-switch controlled from this tank but may be manually operated at the treatment plant.

The treated water supply to the powerhouse and control building first enters the basement of the control building at which point the pressure is reduced to 60 pounds per square inch. Provision has been made for the future installation of a hypochlorinator if necessary in this basement. The sanitary fixtures and air-conditioning equipment in the control building and—by means of a 1½-inch supply line extending across the powerhouse access bridge—the sanitary fixtures in the powerhouse are supplied from this pressure reducing station. Surge tanks and relief valves protect the fixtures and equipment from excessive pressures.

The main supply line from the 1,655-gallon storage tank to the control building also supplies a 450-gallon storage tank located at approximate elevation 1920 northeast of the control building. The water level in this tank is controlled by a float valve, and an overflow line is provided. From this tank treated water flows to the maintenance building, where the pressure is reduced to 50 pounds per square inch for use in the sanitary fixtures. A relief valve also protects this system.

Gravity flow from the 1,655-gallon storage tank supplies the drinking fountains and sanitary fixtures in the picnic area and visitors' building through a separate line. Provision is made for draining this line when freezing temperatures are encountered.

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Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 500-gallon steel septic tank in the powerhouse at elevation 1655. Under normal conditions of tailwater, the effluent from the tank drains directly into the tailrace by gravity through an outlet in the downstream face of the powerhouse substructure. When tailwater rises above elevation 1655, the effluent is diverted to the station sump from which it will be automatically discharged to tailwater through the station drainage system.

The waste from the toilet facilities in the visitors' building in the picnic area discharges into a 2,000-gallon concrete septic tank located approximately 60 feet east of the building. The effluent from the tank discharges into a subsurface tile field.

The waste from the toilet facilities in the control building discharges into a 730-gallon concrete septic tank approximately 27 feet north of the building. The effluent from the septic tank discharges to the tailrace through a 6-inch cast-iron pipe.

The waste from the toilet facilities in the maintenance building discharges into a 540-gallon concrete septic tank 10 feet east of the building. The effluent from the tank discharges into a subsurface tile field.

Drainage and unwatering

The roof drainage of the sluiceway tower and all drainage from the intake tower flows directly to headwater. The sluiceway tower drainage below maximum headwater is discharged to tailwater through the sluiceway discharge tunnel.

A portable gasoline-engine-driven pump with a capacity of 91 gallons per minute is available to unwater the trash pockets in the power conduit when the tunnels are drained.

A series of foundation drains under the surge tank prevent uplift pressure. These drains are normally drained to tailwater through a header embedded in the concrete lining of unit 2 penstock. Provision is made to bypass this drainage to the powerhouse sump.

Drainage above elevation 1669 in the powerhouse flows directly to tailwater, and drainage at elevation 1669 and below flows to the powerhouse drainage and unwatering sump. The sump is located below the elevation 1665 floor at unit 1 adjacent to the service bay and has a capacity of approximately 11,450 gallons. It is serviced by one 425-gallon-per-minute vertical turbine-type pump and one 6-inch eductor having a capacity of approximately 290 gallons per minute with an inlet pressure of 100 pounds per square inch, both of which discharge to tailwater. The pump is operated automatically by float switch controls. The eductor supply valve is throttled to handle all normal powerhouse drainage continuously, and the 425-gallon-per-minute pump acts as a standby for abnormal flow into the sump exceeding the capacity of the eductor.

An unwatering system for the draft tubes and scroll cases is used to permit inspection and repair of turbine runners when tailwater is above the bottom of the runner. Under normal conditions the bottom of the runner is above tailwater and may be inspected without dewatering. Each scroll case intake conduit is equipped with a screened outlet and a 10-inch drain line with a shutoff valve.

When the butterfly valve is closed, the water in the scroll case comes to tailwater level through the wicket gates and through the opened valve in the 10-inch drain line emptying into the draft tube. Each draft tube is constructed with a screened outlet 7 inches above the low point of the draft tube. A 12-inch drain pipe, with shutoff valve, connects each draft tube to the station sump.

One 3,200-gallon-per-minute, vertical, turbine-type pump mounted over the sump operates during unwatering periods. The pump is operated either manually or by float control, and may be used to augment the station drainage pumping capacity. Provision has been made for the ultimate installation of a second unwatering pump, if required.

All roof and building drainage in the control building flows by gravity to an underground drainage system and discharges to tailwater.

Fire protection

A carbon-dioxide fire-extinguishing system is provided for protection of the generators, the oil storage room, and oil purification room in the powerhouse. The system is arranged for remote automatic and local manual operation, and consists of two banks of 50-pound cylinders. One bank of 16 cylinders is a combined initial and reserve bank—8 initial and 8 reserve cylinders, and the other bank contains 8 cylinders for delayed discharge. The initial bank is arranged for the simultaneous discharge of 8 cylinders to either generator. The delayed discharge bank is arranged for intermittent discharges to maintain a sufficient concentration. The reserve bank is arranged with interconnecting piping and controls to function in an emergency the same as the initial bank. The reserve bank normally provides protection for either the oil storage or the oil purification rooms, and is arranged to automatically discharge 8 cylinders to either room.

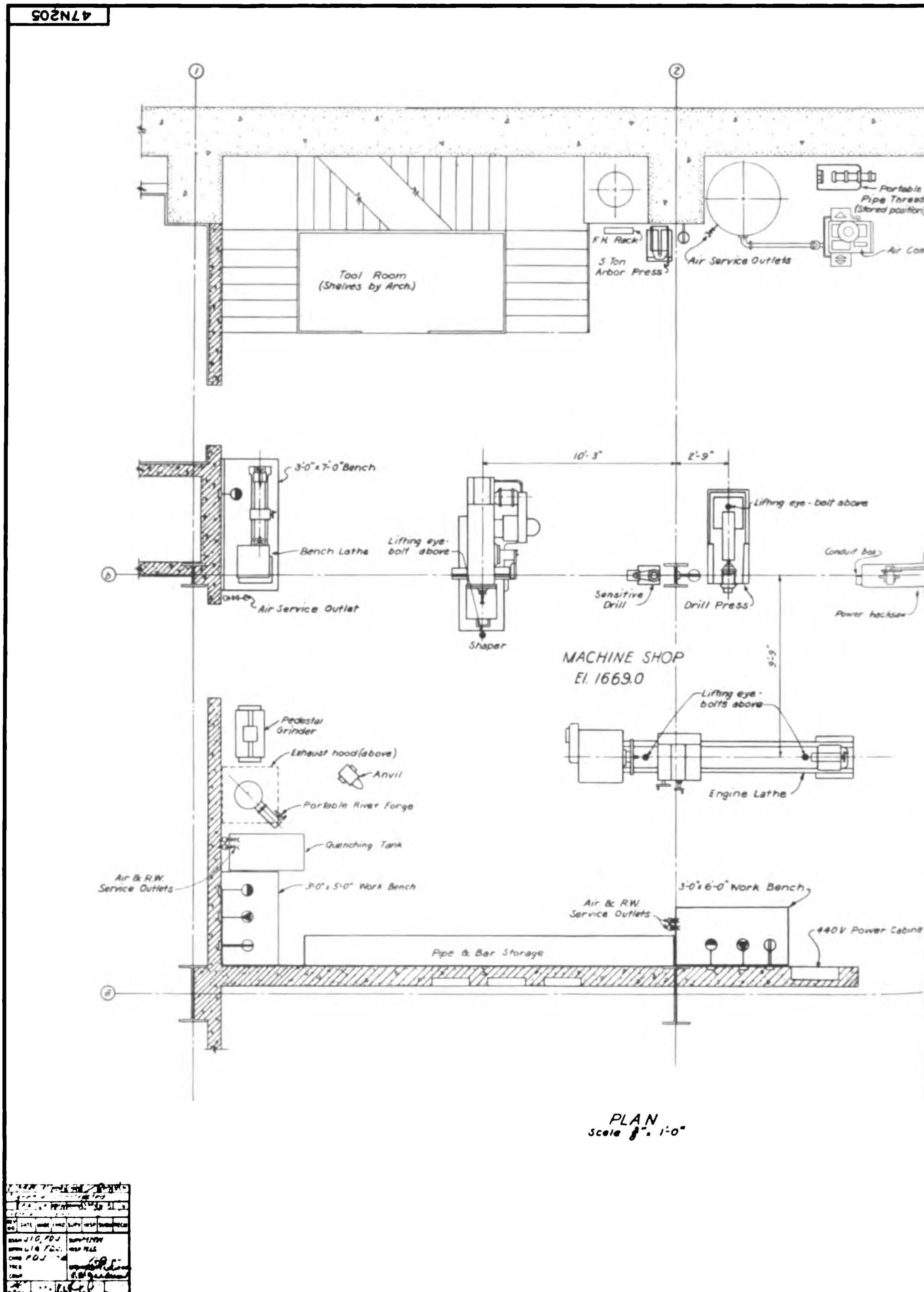
An additional carbon-dioxide system is in the oil purification building in the switchyard. A bank of four 50-pound cylinders is arranged for discharge into the insulating oil purification room.

Portable carbon-dioxide hand extinguishers are in the powerhouse and control building. One 100-pound, wheel-type unit is stored in the oil purification building for use in the switchyard. Water hydrants for hose connections are provided for general fire protection in the powerhouse and switchyard. Numerous fire hose outlets in the powerhouse and control building are equipped with a valve, 75 feet of unlined linen hose on a rack, and a nozzle. One fire hose cart, complete with wrenches, reel, 100 feet of hose, and two nozzles, is stored in the oil purification building for protection of the switchyard and control building area.

The main transformers on the powerhouse deck are provided with an automatic water-spray-type fire-protection system which is described in detail in chapter 13, "Fire Protection."

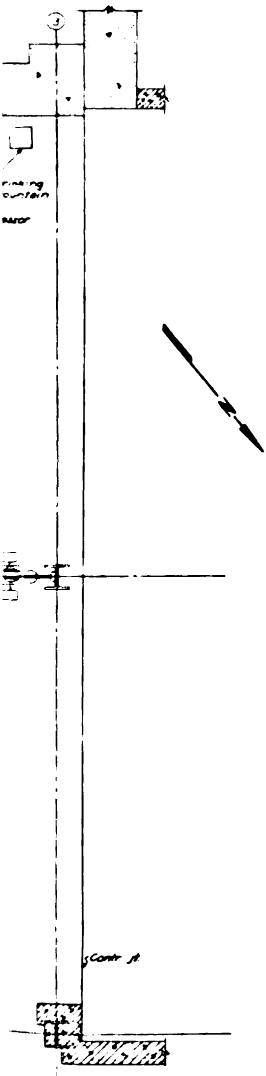
Service equipment

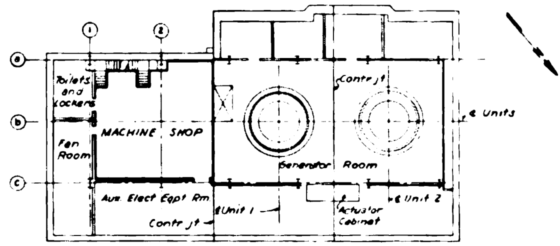
The machine shop, which is conventional size, is in the service bay of the powerhouse adjacent to the generator room. The shop includes equipment as listed in table 14, page 626, and plate 6 shows a general arrangement of the machines.



PLAN

Scale $\frac{3}{8}$" = 1'-0"



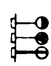


KEY PLAN AT EL 1669.0
Scale 1"=20'-0"

EQUIPMENT LIST			
MACHINE	DESCRIPTION	TVA CONT'R NO.	REMARKS
Engine Lathe	18-inch Western Machine Tool Wks engine lathe, 20¼" swing, 10'-6" between centers, motor 10 hp	W S Murrian Co TV-98880	
Bench Lathe	9-inch South Bend bench lathe, 10¼" swing, 2'-9⅞" between centers; motor ⅜ hp	W S Murrian Co TV-98666	
Shaper	24-inch Western Machine Tool Works shaper, horiz table travel 27⅞"; vert table travel 13⅞", motor 7½ hp	W S Murrian Co TV-98666	
Portable Rivet Forge	Buffalo forge No 210, dia of hearth 18", size of fan 12"	W S Murrian Co TV-98880	
Power Hacksaw	Racine power hacksaw Size of work 8½" x 9⅞"; motor 2 hp	W S Murrian Co TV-98666	
Arbor Press	5 ton capacity Greenerd arbor press	Greenerd Arbor Press Co Order No M45-18182	
Drill Press	30-in Clearman upright drill press, table traverse 15", 8 spindle speeds 50-1000 rpm, motor 5 hp	Bryant Machinery and Engineering Co TV-98667	
Pedestal Grinder	The Cincinnati Electrical Tool Co 12" pedestal grinder; motor 2 hp	Mills & Lupton Supply Co TV-98668	
Portable Pipe Threader	Oster No 502 for cutting & threading ⅛"-2" pipe with attachments for cutting & threading 2½"-8" pipe, motor ½ hp	Moore-Handley Hardware Co inc TV-99120	
Sensitive Drill	10-in Champion No 1500 single spindle sensitive drill, stationary head, 4" feed travel, 5 spindle speeds 450-5100 rpm, motor ⅓ hp	Tenn Mill & Mine Supply Co TV-99119	
Anvil	Solid wrought-iron anvil with length and width of face 17" x 4¾", wt 175 lbs	Mills & Lupton Supply Co TV-98668	
Quenching Tank	⅛" steel plate welded construction, dimensions 2'-0" x 2'-0" x 4'-0"	W S Murrian Co TV-98668	

NOTE All motors indicated above 440 v, 3 ph, 60 cy

SYMBOLS



Electrical outlet - 440V - 3φ
" " - 250 V - DC
" " - 110V

NOTES.
1. For a detail description of equipment see TVA. Std Specification No M-64 for machine shop equipment.
2. All stationary equipment shown to be bolted to the floor with cinch anchor bolts furnished by field. Concrete foundations are not necessary.
3. Work and lathe benches shall be made by the field in accordance with TVA Dwg 508602 Type A bench.
4. Pipe and bar storage rack to be furnished and fabricated by Power Dept.

NOT TO SCALE

Scales as noted

POWERHOUSE
SERVICE BAY

MECHANICAL EQUIPMENT
MACHINE SHOP
GENERAL ARRANGEMENT

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

RECOMMENDED — REVIEWED — APPROVED

THIS DRAWING SUPERSEDES DRAWING OF SAME NUMBER DATED 5-11-45

KNOXVILLE | 10-31-46 | 22 | M | 4 | 47N205 R2

PLATE 6

An automatic pushbutton-controlled electric elevator is installed for the use of operating personnel in the sluiceway tower. The total lift is from the top to bottom landings, approximately 225 feet, with no intermediate landings. The elevator has a rated live load capacity of 1,200 pounds at a car speed of 100 feet per minute. Design data covering this machine are included in table 6, page 394.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, lobby, telephone room, and offices of the control building; the remainder of the control building, the visitors' building, and the powerhouse are mechanically ventilated. Electric unit heaters throughout these buildings and the sluiceway tower provide heat to rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Heated air exhausted from the powerhouse electrical equipment rooms may be recirculated to the powerhouse during cold weather to conserve heat. Portable electric heaters supplement the permanently connected heaters as required.

The air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of lake water through the cooling coils.

The combined capacities of the heating and ventilating systems are as follows:

Cubic feet per minute of air supplied and exhausted	148,100
Kilowatts of installed electric heating	505

WILBUR

The Wilbur project is on the Watauga River at mile 34.7, a distance of 1.8 miles downstream from the Watauga powerhouse. The original plant was built by the Watauga Power Co. during the years 1910 to 1912 and was acquired by TVA on June 29, 1945, from the East Tennessee Light & Power Co. At that time the generating facilities consisted of three units with a total rated generating capacity of 3,700 kilowatts.

Construction of the Watauga project provided stream flow regulation and justified the addition of a fourth unit at the Wilbur project. The project was extensively renovated, including the construction of an additional intake and powerhouse extension adjacent to the original powerhouse. Principally a power project, the Wilbur station now has a total generating capacity of 10,700 kilowatts and only 327 acre-feet of storage. Authorization, operation, and cost data of the completed project are as follows:

Authorization (unit 4)	September 25, 1947
Commercial operation:	
Units 1 and 2	1912
Unit 3	1926
Units 1 and 2 rebuilt	1928–1929
Unit 4	July 19, 1950
Cost of the 4-unit project (acquired cost to TVA plus cost of TVA improvements), including switchyard	$2,550,424

The original plant consisted of a concrete dam with flashboard-controlled spillway and a powerhouse and switchyard located at the

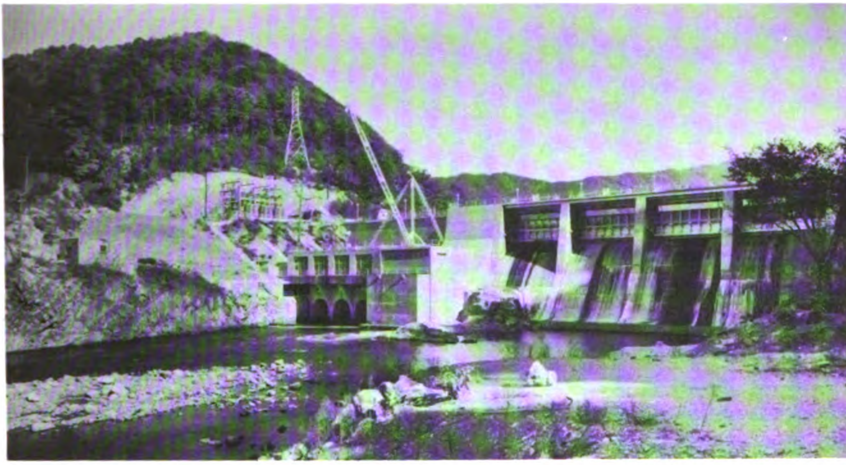


Figure 116.—*Wilbur project in 1950 upon completion of renovation program.*

toe of the dam on the right side of the river. The initial power installation consisted of two double runner horizontal units, and a vertical unit was added in 1926.

The renovated project is shown in figure 116. An elevation, plan, and sections are shown in figure 117.

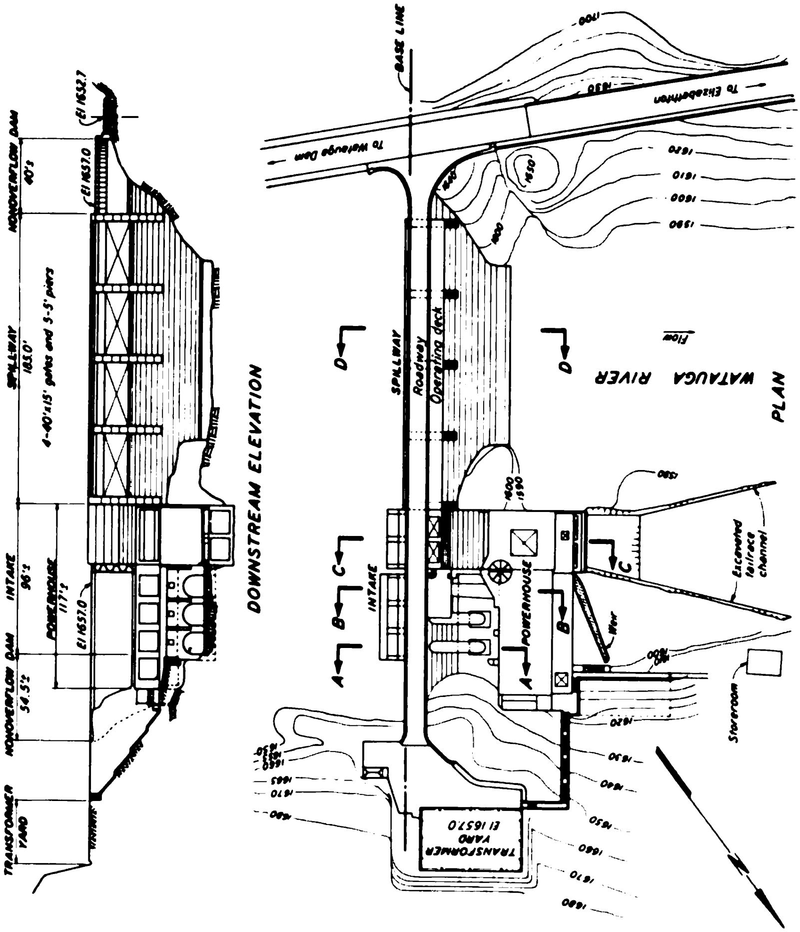
Alterations included cutting off the crest of the old spillway, adding concrete to the downstream face, and building a new crest at a lower elevation. Piers were constructed, and four 40-foot-wide by 15-foot-high radial gates were installed. The original intake was raised, thereby furnishing chambers for the operating machinery of the old intake gates. The nonoverflow section of the dam was raised and widened. The downstream faces of the dam and intake sections, which were badly weathered, were repaired. A new left abutment was constructed on top of the old abutment. The new construction provided an 11-foot-wide roadway across the dam to the new transformer yard on the right bank.

A 40-ton-capacity stiffleg derrick was installed on the old powerhouse roof. The derrick was used in the construction of unit 4 and left in place to handle the intake and draft tube gates, and for maintenance of the unit. The roof of the old powerhouse was used as an erection area.

The unit 4 powerhouse is the semioutdoor type, consisting of a block 37 feet wide by 63 feet long. There is a 17-foot-square hatch in the roof, through which the turbine and generator parts are moved. Equipment rooms and the pipe galleries are downstream from the scroll case and located above the elbow-type draft tube.

Turbines

Units 1 and 2 are the horizontal Francis type originally manufactured by the S. Morgan Smith Co. and later rebuilt with parts furnished by The James Leffel & Co. They are rated 1,900 horsepower at 55-foot net head and operate at a speed of 360 revolutions per minute. Unit 3 is the vertical Francis type manufactured by


TRANSFORMER YARD
NONOVERFLOW DAM 54.5'±
POWERHOUSE 117'±
INTAKE 96'±
SPILLWAY 183.0'
4-40'x15' gates and 5-5' piers
NONOVERFLOW DAM 40'±
El 1657.0
El 1632.7
DOWNSTREAM ELEVATION
BASE LINE
To Watauga Dam
To Elizabethton
SPILLWAY
Roadway
Operating deck
INTAKE
POWERHOUSE
Weir
Excavated tailrace channel
Storeroom
Flow
WATAUGA RIVER
TRANSFORMER YARD
El 1657.0
PLAN

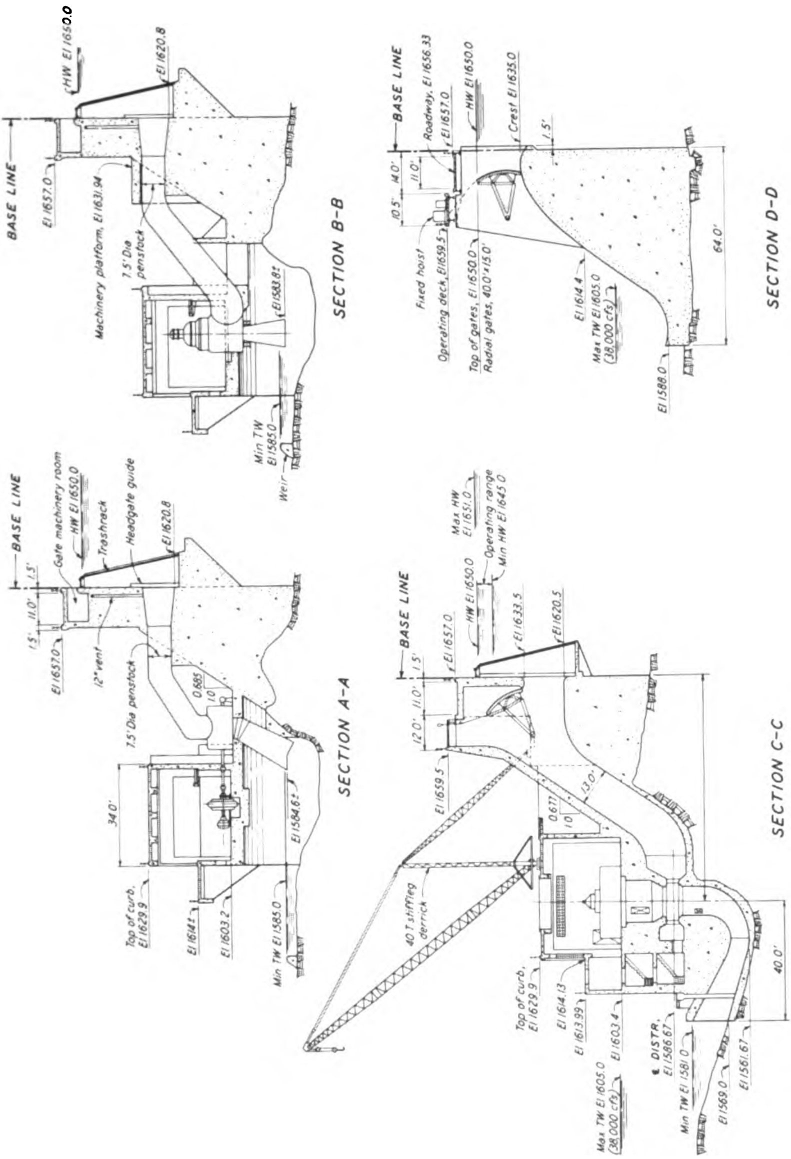


Figure 117.—*Wilbur—plan, elevation and sections.*

The James Leffel & Co. It is rated 1,840 horsepower at 55-foot net head and operates at a speed of 277 revolutions per minute.

Unit 4 is the vertical fixed-blade propeller type manufactured by The James Leffel & Co. It is rated 9,700 horsepower at a net head of 58 feet and operates at a speed of 180 revolutions per minute. It is designed to operate satisfactorily under any head from a minimum of 58 feet to a maximum of 69 feet and is most efficient at a head of about 62 feet. The maximum runaway speed for which the unit is designed is 467 revolutions per minute. At rated conditions the value of specific speed is 111, and the center line of the runner is set about 1 foot below normal tailwater elevation, giving a plant sigma of 0.51.

Unit 4 has a concrete spiral case and cast-steel stay ring. The stay ring forms the main foundation ring for the turbine and the 10 stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. The runner is an integral steel casting with six blades. Certain areas on the discharge side of each blade were prewelded with stainless steel to prevent pitting. Water to the runner is controlled by 20 cast-steel wicket gates. The turbine shaft is guided by a water-lubricated bearing of molded plastic or Insurok material.

Governor

The governor for unit 4 is a single cabinet-actuator type (fig. 118) manufactured by the Woodward Governor Co. It is complete with governor head, sump tank, pressure tank, oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the Watauga control building. The two herringbone gear-type oil pumps, each with a capacity of 40 gallons per minute at 300 pounds per square inch, are driven by two 10-horsepower motors. One of these pumps supplies oil to the pressure tank, and the other operates as a spare. The sump tank is in the base of the cabinet. The pressure tank is inside the cabinet and has a volume of 32 cubic feet.

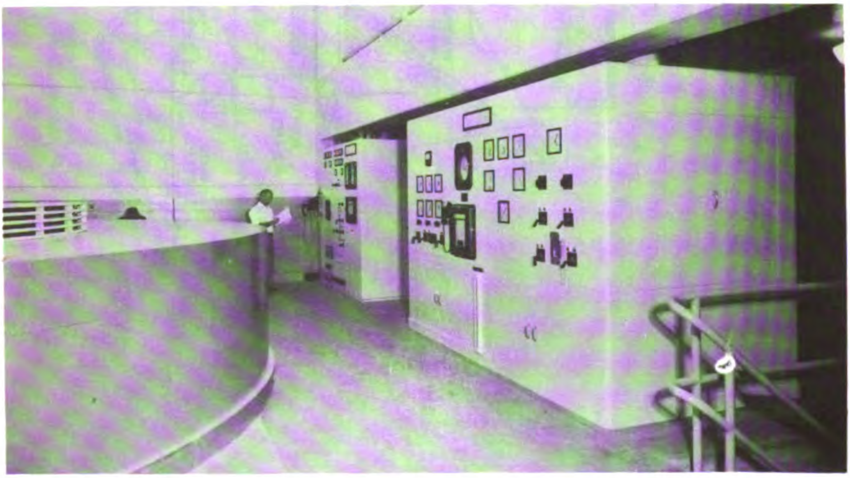


FIGURE 118.—*Wilbur—generator room extension for unit 4.*

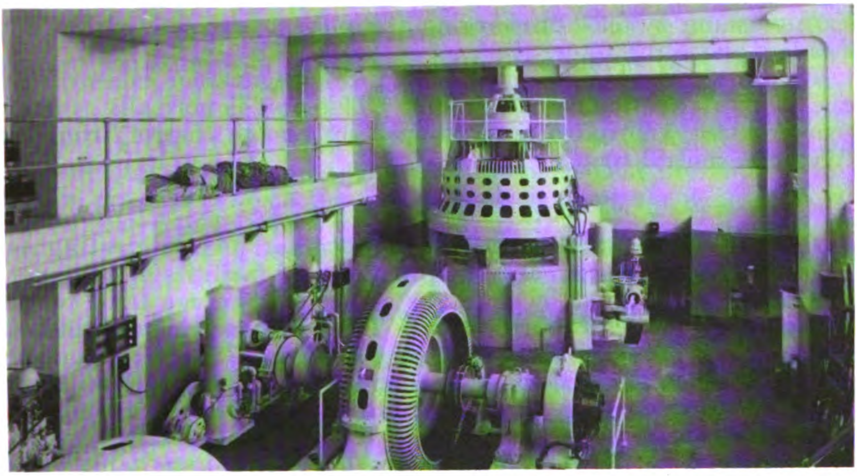


FIGURE 119.—*Wilbur—generator room for original units 1, 2, and 3.*

Generators

The generators of the three units in the old powerhouse are open-frame, air-cooled machines. Units 1 and 2, manufactured by the Westinghouse Electric Corp., are horizontal-type units rated 1,560 kilovolt amperes, 1,250 kilowatts, 0.8 power factor, 2,200 volts, 3 phase, 60 cycles, and operate at 360 revolutions per minute. Unit 3, also manufactured by the Westinghouse Electric Corp., is a vertical-type generator rated 1,500 kilovolt amperes, 1,200 kilowatts, 0.8 power factor, 2,300 volts, 3 phase, 60 cycles, and operates at 277 revolutions per minute. A view of the old generator room containing these units is shown in figure 119.

Unit 4, in the new addition to the powerhouse, was placed in service in 1950. The generator, manufactured by the Elliott Co., has a normal rating of 7,777 kilovolt amperes, 7,000 kilowatts, 0.9 power factor, 2,300 volts, 3 phase, 60 cycles, and operates at 180 revolutions per minute with a maximum runaway speed of 467 revolutions per minute. Unit 4 generator is totally enclosed and water cooled with two heat exchangers within the air housing, through which the air is circulated. The generator is a vertical type with a Kingsbury type thrust and segmental guide bearing, which is located below the rotor and immersed in an oil reservoir with a capacity of 340 gallons. Cooling coils in the generator bearing oil reservoir are designed for a flow of 9 gallons per minute with 25 centigrade water temperature.

Unit 4 generator is equipped with 12 combination brakes and jacks which are mounted on the lower bearing bracket and bear against the brake ring on the underside of the rotor rim. Compressed air at 100-pound-per-square-inch pressure is supplied for braking from the station compressed air system and is automatically controlled. Oil pressure for jacking is applied at 900 pounds per square inch by means of a portable hand-operated oil pump.

Generator fire protection is provided by a carbon-dioxide fire-extinguishing system, discharging through nozzles located in ring headers above the rotor.

Figure 118 shows the unit 4 generator and governor cabinet with the switch board in the background. This unit is normally started, synchronized, controlled, and stopped by remote control from the Watauga control room.

Oil systems.

Because of the small quantity of governor and lubricating oil required for this station and the proximity of facilities at Watauga, the oil is transported by truck in a portable storage tank to the Watauga project for purification. The governor and lubricating oil facilities provided for unit 4 consist of one 785-gallon portable oil storage tank, one 20-gallon-per-minute oil transfer pump, and a complete piping system to transfer oil for the governor system and generator bearing from the portable tank. The used oil is drained by gravity from the equipment to the portable storage tank which is located on the lower floor of the equipment bay. The tank is then handled by the derrick through hatches for transporting.

No insulating oil storage tanks or purification facilities are provided for the electrical equipment at this project. The portable insulating oil purifier provided for the Watauga project is intended to be moved to Wilbur for direct connection to the electrical equipment when the oil requires purification. Any major repairs to the Wilbur electrical equipment, which would require complete draining of the oil, are to be made at Watauga.

Compressed air system

A compressed air system, utilizing the stationary, 8.3-cubic-foot-per-minute, air-cooled governor air compressor, is provided in the new powerhouse for station air service and the generator air brakes. The compressor, with an available discharge pressure of 300 pounds per square inch, is automatically controlled to supply the 100-pound-per-square-inch station air system. A complete piping system and a 38-cubic-foot air receiver supply compressed air to the generator brakes, station service outlets, and for instrument control of the generator cooling water proportioning valve.

The governor oil pressure tank, inside the governor cabinet, is supplied by manual operation of the compressor at 300-pound-per-square-inch pressure. The pressure is frequently checked, and the air supply replenished as required.

Raw water system

Raw water for unit 4 cooling and lubricating and for several raw water service connections is obtained from an intake in the unit 4 scroll case. The water flows by gravity through a twin strainer.

A motor-operated gate valve is provided for manual remote control from the Watauga control room of the water supply to the unit. Three branch lines to the unit provide cooling water to the two generator surface air coolers, cooling water to the generator bearing oil coolers, and lubricating water to the turbine guide bearing. Each of the three lines is equipped with an indicating flow-

meter having two electrical contacts which close on low flow. One contact sounds an alarm at Watauga control building, and the other contact shuts down or prevents starting the unit on low flow.

Flow through the unit 4 generator air coolers is automatically controlled by an air-operated proportioning valve operated by a temperature controller which is actuated by a thermometer bulb in the generator housing. An antisyphon arrangement prevents draining the air coolers when the water supply is stopped.

Raw water is also provided for use in the plumbing fixtures at this station. A sign located over the lavatory warns that the water is not suitable to drink.

Treated water system

There is no treated water system at this project. Bottled water is used for drinking purposes.

Sewage disposal

The waste from the employees toilet facilities in the powerhouse discharges into a 540-gallon concrete septic tank approximately 25 feet downstream from the powerhouse. The effluent from the septic tank discharges into the tailrace through a 4-inch pipe, terminating at elevation 1584.5.

Drainage and unwatering

All powerhouse roof and deck drainage flows by gravity to the tailrace. All other drainage flows to the station sump. The sump has a capacity of approximately 370 gallons and is serviced by two 50-gallon-per-minute sump pumps discharging directly to the tailrace. The pumps are operated by float switch controls, which also sound an alarm at Watauga control building for high water level in the sump.

An unwatering pump for the draft tube and scroll case is used to permit inspection and repair of the underwater parts. The scroll case is equipped with a screened outlet and an 8-inch drain line with shutoff valve. When the intake gates are closed, the water in the scroll case drains to tailwater level through the wicket gates and the opened 8-inch drain valve into the draft tube before the draft tube gates are closed. The draft tube is equipped with a screened outlet which connects to a 24-inch unwatering pump well.

One 1,500-gallon-per-minute, vertical, turbine-type pump installed in the 24-inch well operates during unwatering periods and discharges directly into the tailrace. This pump is manually controlled.

Fire protection

An automatic carbon-dioxide fire-extinguishing system protects unit 4 generator. The system is arranged for remote automatic operation by means of thermostats or generator differential relay and for manual operation from a control switch. One bank of eight 50-pound cylinders is provided, 4 of which supply the initial discharge by simultaneous release to the generator housing, and the remaining 4 cylinders are arranged for intermittent release to main-

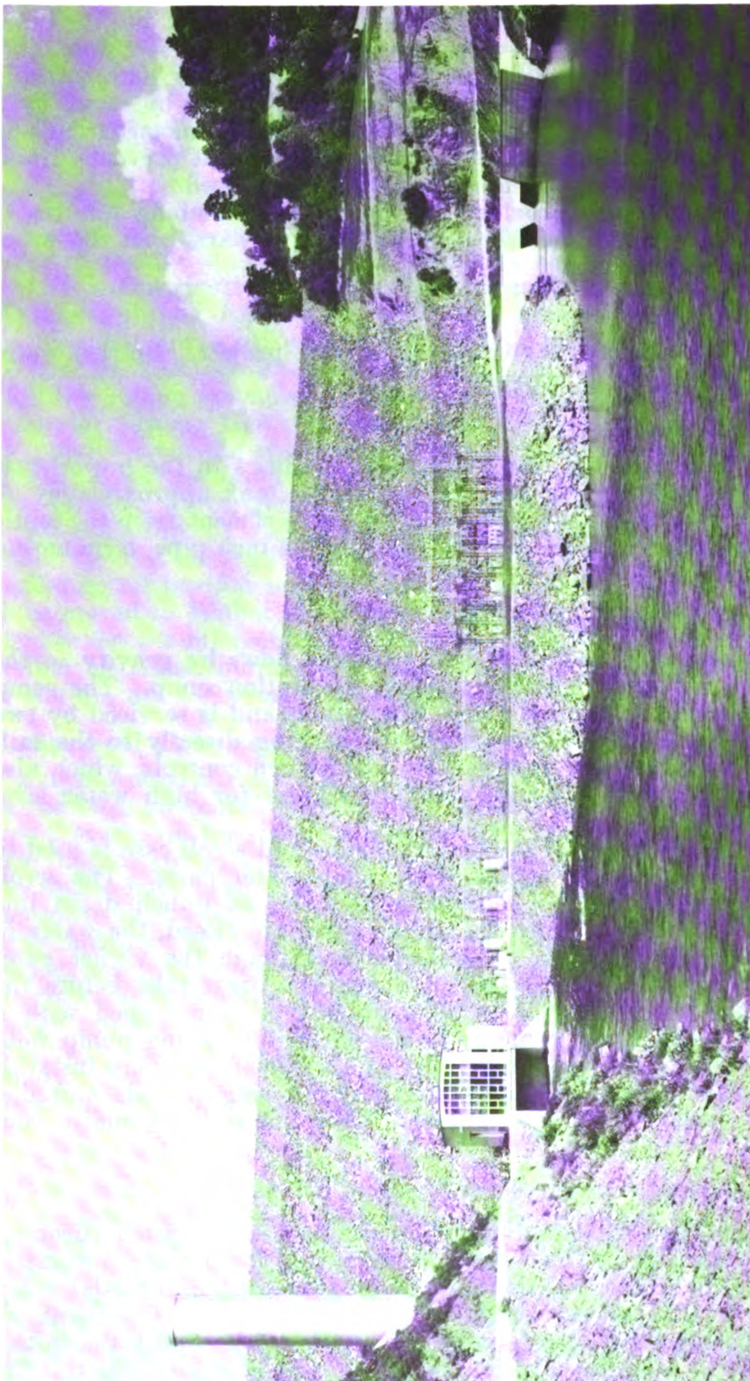


FIGURE 120.—*South Holston project.*

tain a sufficient concentration in the generator housing. The generator has an air volume of 1,740 cubic feet.

The transformer yard is equipped with an adjacent concrete fire-protection equipment building which houses portable carbon-dioxide fire extinguishers. No water fire-protection system is installed at this yard.

Portable hand extinguishers are provided for general fire protection in the powerhouse.

Service equipment

There is no machine shop equipment at this project. Any repairs to the powerhouse equipment are to be made in the Watauga machine shop.

Heating and ventilating

The unit 4 powerhouse is mechanically ventilated for the removal of heat from electrical equipment or solar radiation and for the relief of dampness. Electric unit heaters throughout the powerhouse heat rooms or areas where occasional occupancy during inspection or repairs may be expected and where freezing or excessive dampness may occur. Portable electric heaters serve to supplement the permanently connected heaters as required.

The combined capacities of the heating and ventilating systems are as follows:

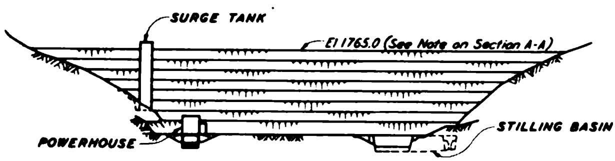
Cubic feet per minute of air supplied and exhausted	9,200
Kilowatts of installed electric heating	54

SOUTH HOLSTON

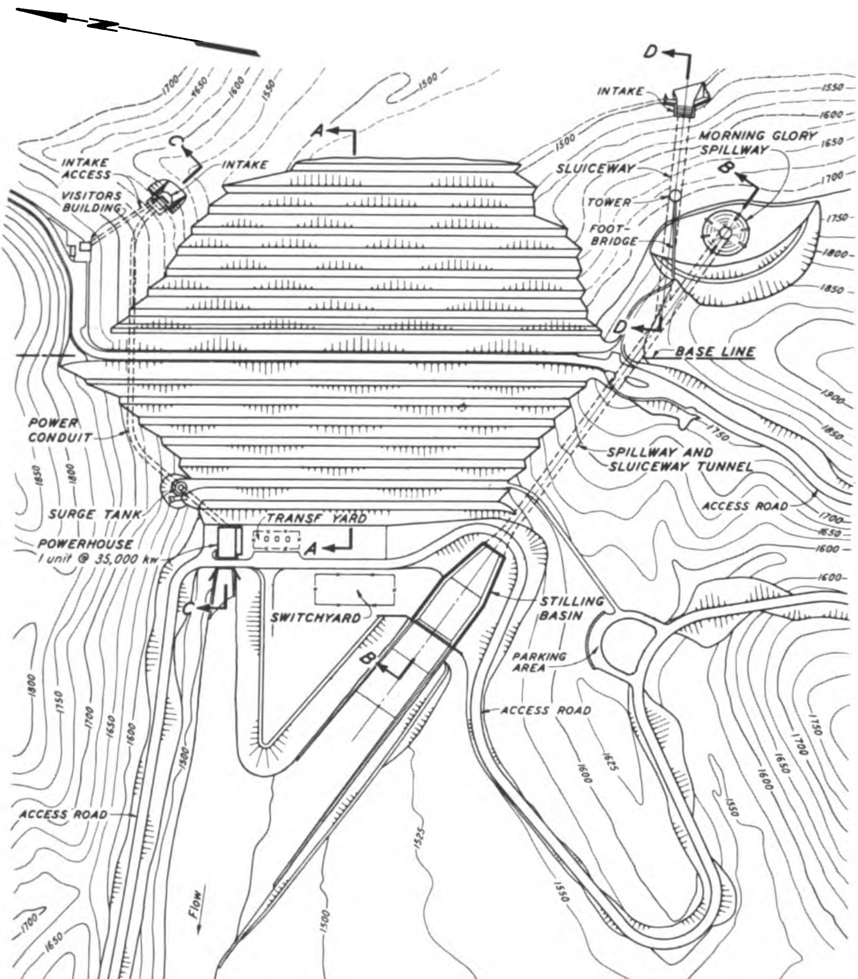
The South Holston Dam is on the South Fork Holston River at river mile 49.8 near Bristol, Tenn. The project is a combined power and flood control type, contributing a generating capacity of 35,000 kilowatts from the single unit and providing a useful controlled storage volume of 625,200 acre-feet, of which 105,800 acre-feet must be preserved throughout the year for flood storage. Construction of Watauga and South Holston projects, which are similar in most respects, was planned to run concurrently for optimum usage of construction equipment and manpower. Congress appropriated funds for the project in December 1941 and construction was started in February 1942. The work was discontinued in April 1943 because of shortage of critical materials, and subsequently resumed in August 1947. Authorization, construction, operation, and cost data are as follows:

Authorization	January 15, 1942
Construction started	February 16, 1942
Dam closure	November 20, 1950
Commercial operation	February 13, 1951
Cost of the single-unit project, including switchyard	$31,213,245

Figure 120 is a view of the dam from a point near the junction of the tailrace and the spillway discharge channel. The principal features of the project (fig. 121) include: the main dam, and a saddle dam located on the right rim about 5 miles northeast of the main dam; outlet works consisting of a morning-glory spillway, a

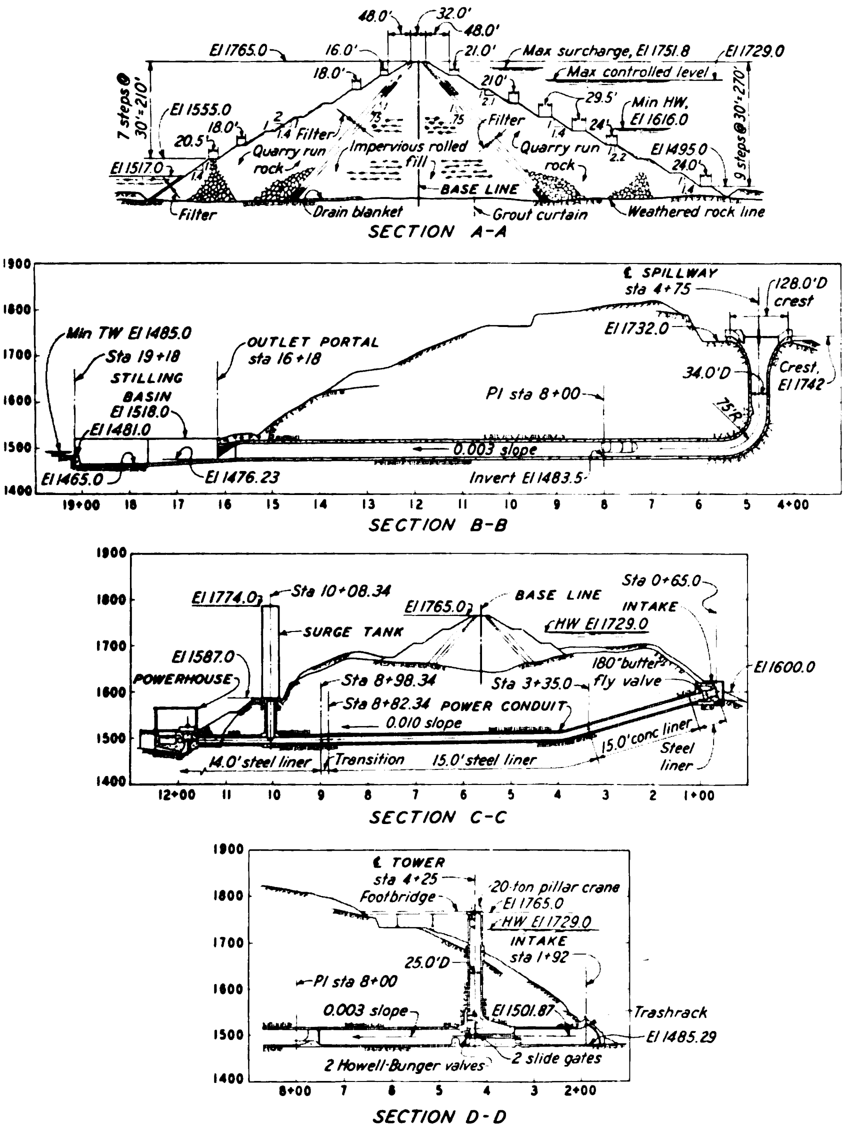


DOWNSTREAM ELEVATION



PLAN

FIGURE 121.—*South Holston*—



plan, elevation, and sections.

low level valve-controlled sluiceway, and an auxiliary spillway; and power facilities consisting of a submerged intake chamber, a power conduit with surge tank in the right abutment, and a powerhouse at the toe of the main dam.

The main dam is an earth and rock fill structure with a maximum height of 285 feet. The top width is 32 feet, and the maximum base width is about 1,175 feet. The crest of the dam is approximately 1,600 feet long.

The morning-glory spillway and the sluiceway both discharge into a tunnel in the left bank. Flow over the crest of the spillway, which has a crest diameter of 128 feet, is uncontrolled. The water discharges into a vertical shaft and then through an elbow section into the nearly horizontal portion of the 34-foot-diameter, concrete-lined outlet tunnel. From the outlet portal the flow discharges into a stilling basin.

The sluiceway tunnel, which was used for diversion of the stream flow during construction, has a closure plug containing two 5.67- by 10-foot water passages controlled by two 96-inch diameter Howell-Bunger valves. Upstream from each valve is an emergency slide gate. Access to the tunnel and valve operating chamber is through a 25-foot-diameter concrete shaft, which is covered by a platform. A footbridge connects the platform to the shore.

The intake, at the right abutment of the dam, consists of a watertight chamber containing a 180-inch butterfly valve, and the necessary auxiliary equipment. Downstream from the butterfly valve are installed a vacuum relief valve and an 8-inch penstock vent. The vent extends up into the basement wall of the visitors' building. Air for the vacuum relief valve is drawn in through a hatch in this building and through the access tunnel to the valve chamber. The inclined access tunnel contains tracks for a 2-man cable car and a stairway for emergency use.

The power conduit is a tunnel approximately 1,120 feet long, excavated in the rock of the right abutment. The tunnel is steel lined for a distance of 845 feet and the balance is concrete lined. The 15-foot-diameter tunnel is reduced to 14 feet at a point 126 feet upstream from the surge tank. The restricted orifice type surge tank is located on a rock ledge at the dam and connected to the conduit by a vertical shaft excavated in rock. The tank and orifice are of welded steel construction.

The powerhouse, at the toe of the dam, is the indoor type. The main structure shown in figure 122 is approximately 50 feet wide by 86 feet long, with an adjoining 2-story electrical bay. The substructure is reinforced concrete, and the superstructure is structural steel with insulated aluminum siding and roofing.

The transformer yard is adjacent to the powerhouse, and the switchyard is on the filled area between the tailrace and the spillway discharge channel.

Turbine

A single vertical Francis-type hydraulic turbine manufactured by the S. Morgan Smith Co. is direct-connected to the generator. The turbine is rated 48,500 horsepower at a net head of 180 feet and operates at a speed of 144 revolutions per minute. It is designed to operate under any head from a minimum of 126 feet to a maximum

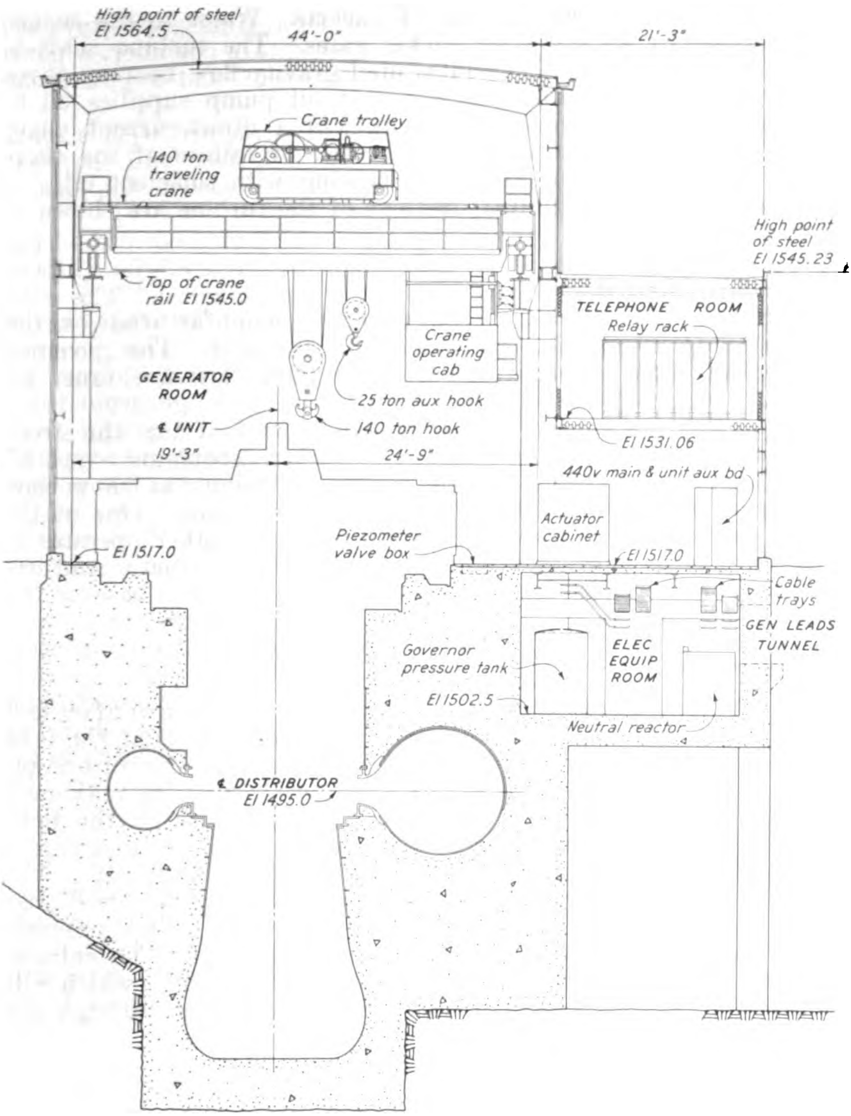


FIGURE 122.—*South Holston powerhouse section.*

of 252 feet and is most efficient at a net head of about 205 feet. The maximum runaway speed for which the unit is designed is 267 revolutions per minute. At rated conditions the value of specific speed is 48, and the centerline of the runner is set about 6 feet above normal tailwater elevation, giving a plant sigma of 0.163.

A cast-steel stay ring forms the main foundation ring of the turbine, and the 20 stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. The spiral case is of riveted plate-steel construction. The casing plates were formed to a continuous circular transition instead of a series of chords between the circumferential joints. The runner is

an integral steel casting and has 17 buckets. Water to the runner is controlled by 20 cast-steel wicket gates. The turbine shaft is guided by a babbitt-lined, oil-lubricated gravity flow bearing above the head cover. An alternating-current oil pump supplies oil to the bearing under normal conditions, and a direct-current pump comes into operation automatically in case of failure of the alternating-current pump to supply the bearing with sufficient oil.

Transverse and longitudinal sections of the turbine are shown in figure 123.

Governor

A single cabinet-actuator-type governor manufactured by the Woodward Governor Co. is provided for the unit. The governor is complete with governor head, sump tank, pressure tank, oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the Watauga control building. The two herringbone gear-type oil pumps, each with a capacity of 150 gallons per minute at 300 pounds per square inch, are driven by 40-horsepower motors. One of the pumps supplies oil to the pressure tank, and the other operates as a spare. The pressure tank is directly behind the actuator and has a volume of 123 cubic feet. The sump tank is in the base of the governor cabinet.

Butterfly valve

One 180-inch butterfly valve of split body design manufactured by the Newport News Shipbuilding & Dry Dock Co. is at the inlet end of the penstock. The valve is equipped with a 10-horsepower direct-current motor and is set to open or close under maximum head in 300 seconds. The clear area with the disk in the open position is 83 percent of the cross sectional area, and the guaranteed maximum leakage at 150-foot head is 65 gallons per minute.

An 18-inch bypass permits filling the penstock and scroll case before the valve is opened. A differential pressure switch prevents the opening of the valve before the penstock is filled. The valve is equipped with an automatic, high velocity, closing switch which will function to close the valve in case of excessive flow through the turbine.

Generator

The generator, manufactured by the Westinghouse Electric Corp., has a normal rating of 38,888 kilovolt-amperes, or 35,000 kilowatts continuous output at 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and 144 revolutions per minute. The rotor is designed for a maximum runaway speed of 288 revolutions per minute. The unit is a vertical shaft type with a totally enclosed generator, cooled by air circulation through six water-cooled heat exchangers within the housing. The exciters are mounted on the upper bracket and are directly connected to the generator shaft.

The rotor is of umbrella design with a cast-steel spider and a rim of laminated steel. Six double-cylinder combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air at

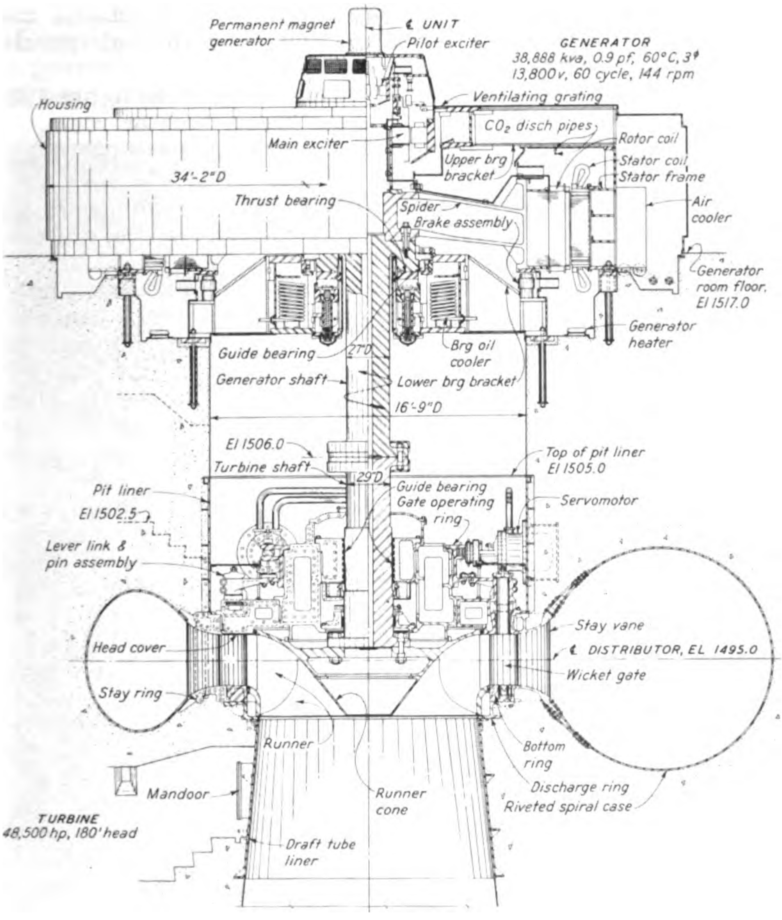


FIGURE 123.—*South Holston—turbine and generator sections.*

100 pounds per square inch is supplied for braking by the station compressed air system and is automatically controlled. Oil pressure at 1,900 pounds per square inch for jacking is applied by a portable hand-operated oil pump.

The combination Kingsbury-type thrust and segmental guide bearing is below the rotor. The bearing is immersed in oil which is cooled by water circulated in coils immersed in the oil reservoir.

Generator fire protection is provided by an automatic carbon-dioxide fire-extinguishing system, discharging through nozzles located in ring headers above the rotor.

A sectional elevation of the generator is shown in figure 123, and figure 124 is a view of the South Holston generator room.

Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are in the equipment rooms on the downstream side of the unit above the draft tube, on the elevation 1486.5 floor. The storage facilities consist of one clean-oil and one dirty-oil tank, each of 2,100-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 24-gallon-per-minute capacity. The system includes a purifier of 350 gallon-per-hour capacity. A complete piping system supplies and returns oil for the governor system and the turbine and generator bearings from the purification and storage equipment. The system is arranged to prevent mixing of clean and dirty oil.

The insulating oil storage tanks, pumps, and purification equipment are on the same floor adjacent to the lubricating oil equipment. The storage facilities consist of three 7,040-gallon tanks, 1 for dirty transformer oil, 1 for dirty circuit breaker oil, and 1 for clean insulating oil. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 120-gallon-per-minute capacity. The system includes a purifier with filter press, providing a purifying capacity of 600 gallons per hour without the press or 900 gallons per hour with the press. A complete insulating oil piping system transfers oil as required. Supply and return lines are provided to the transformer repair bay in the powerhouse machine shop and to conveniently located valve boxes in the transformer yard and switchyard. All connections between the electrical equipment and the piping system are made with flexible hose through 2-inch drain and 1½-inch fill connections. The system is arranged to prevent mixing of clean and dirty oil.

The two sluice gates, which serve as emergency gates for the Howell-Bunger valves in the sluiceway, are raised and lowered by means of hydraulic cylinders above the bonnet of each valve. Oil pressure for operation of the cylinders is supplied by a 20-gallon-per-minute pump with a discharge pressure of 1,200 pounds per square inch. The pump, together with a 330-gallon oil storage tank, is located in the sluiceway tower on the elevation 1546.2 landing. A complete piping system conveys the oil to and from the cylinders.

Compressed air systems

A compressed air system, utilizing the stationary 20.5-cubic-foot-per-minute, air-cooled governor air compressor, is provided in the

powerhouse for the generator brakes, service outlets, and for instrument control of the raw and treated water pressure reducing stations. The compressor, with an available discharge pressure of 300 pounds per square inch, is automatically controlled to supply the 100-pound-per-square-inch station air system. A complete piping system is installed, including a 100-cubic-foot-air receiver.

Provision is made for a possible future connection from the station air receiver to the turbine head cover, for draft tube evacuation if required.

The governor oil pressure tank, on the floor below the governor cabinet near the compressor, is supplied by manual operation of the

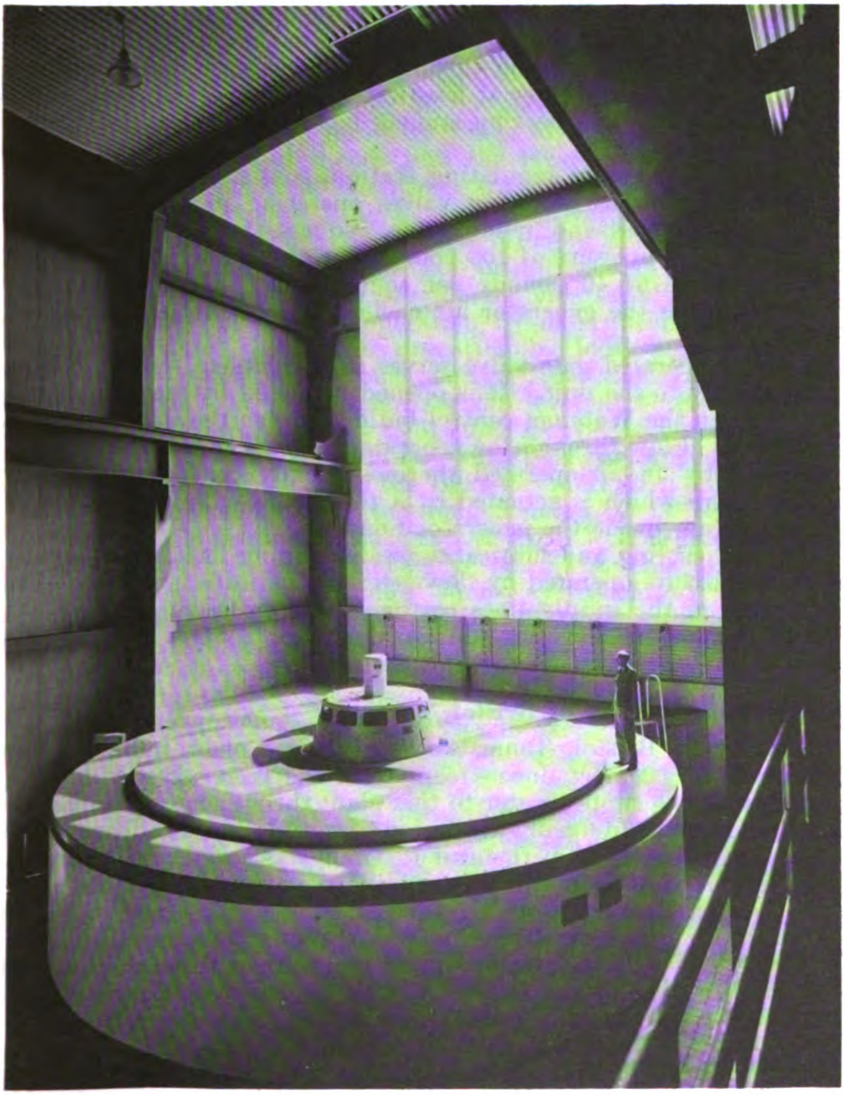


FIGURE 124.—*South Holston generator room.*

compressor at 300-pound-per-square-inch pressure. The pressure is frequently checked, and the air supply replenished as required.

A portable, air-cooled, single-stage, electric-motor-driven, air compressor of 94-cubic-foot-per-minute capacity at 100-pound-per-square-inch pressure is available for general service where required. This compressor is intended to be used during periods of construction or repair work when the demand for compressed air is greater than the capacity of the stationary air compressor. The portable compressor may be connected into the powerhouse air system through a service connection in the machine shop.

Raw water system

Raw water from the forebay is supplied for unit cooling and lubrication by gravity flow from an intake in the scroll case. From a 10-inch twin strainer the turbine and generator water requirements are supplied. Water at headwater pressure is supplied to the turbine seal rings and bearing stuffing box and to the turbine bearing oil cooler.

A complete pressure regulating station, consisting of two 4-inch air-operated pressure reducing valves operating in echelon with a globe valve bypass and relief valve, reduces the pressure from a maximum inlet pressure of 108 pounds per square inch to a constant outlet pressure of 40 pounds per square inch. This low-pressure system supplies the generator air coolers and generator bearing oil coolers.

A motor-operated gate valve serves as a complete shutoff for all water supply to the unit. It is opened or closed by manual remote control from the Watauga control building when the unit is started or stopped. Flow through the generator air coolers is automatically controlled by an air-operated thermostatically controlled, proportioning valve which is actuated by a thermometer bulb mounted in the air stream inside the generator housing.

The unit cooling and lubricating water supply has its own series of alarm circuits operated by flowmeters to indicate low flow. The flowmeters in the supply lines to the generator bearing oil coolers and to the turbine have an additional electric contact which shuts down or prevents starting the unit on low flow.

Water supply to City of Bristol, Tenn.

The city of Bristol, Tenn., water-treatment plant intake is approximately 7,000 feet downstream from the dam. It was TVA's responsibility to supply water to this plant throughout the dam construction period and during the period of initial reservoir filling after closure of the dam. A permanent low dam was constructed immediately downstream from the city intake to impound water released from the main dam reservoir.

During the reservoir filling period the city water supply was maintained by a 14-inch valved pipeline installed through the concrete closure plug of the sluiceway with approximately 400 feet of temporary pipe routed through the sluiceway discharge tunnel to convey water to the downstream river channel.

Several alternate methods of providing a permanent supply were investigated, including the provision of multiple-valved intakes lo-

cated at different reservoir levels to ensure drawing water from the most favorable depth for ease of treatment. Such intakes would have been connected to a single main which in turn would have been routed directly to the city treatment plant. This scheme would have eliminated the need for the low dam finally installed below the city intake. The multiple intake scheme was not adopted largely due to the considerable cost involved and the shortage of critical pipeline materials during this period. A further disadvantage of this scheme was that practically all the water consumption by the city would constitute a loss to TVA in equivalent power generation which would amount to several times that saved by the city by elimination of their low head pumping facilities. This was because the head available in the reservoir for power generation would be several times the head required by the existing city intake pumps.

The scheme finally adopted and installed consists of a 14-inch intake line through the plug of the sluiceway intake tunnel, connected to a Howell-Bunger valve which discharges directly into the sluiceway tunnel and thence into the river downstream from the dam. Under all normal conditions, with the powerhouse generating unit in operation, the 12-inch regulating valve is closed and the water released through the turbine provides a supply at the city intake. When the turbine is not operating the 12-inch Howell-Bunger valve is opened to provide the city supply. The valve is arranged for (1) manual operation by handwheel directly at the valve floorstand, (2) motor operation by local push button, and (3) remote operation by push button from the Watauga project control room. At minimum reservoir level of elevation 1616 the valve full discharge capacity is 31 cubic feet per second and at maximum reservoir elevation 1729 the full discharge capacity is over 46 cubic feet per second. Thus the valve has more than ample capacity to supply the present city pumping demand of 4.6 cubic feet per second and the maximum plant capacity of 7.7 cubic feet per second.

The 12-inch valve shown in figure 125 is the same in principle as the two 96-inch Howell-Bunger sluiceway discharge valves at this project. The extremely fine discharge spray provides beneficial aeration for water drawn from the low reservoir levels to assist in removal of any objectionable taste or odors. Further aeration is afforded the discharged water by traversing the river channel a distance of some 7,000 feet to the city intake.

Treated water system

All treated water for fire protection, drinking, and sanitary use in the powerhouse, switchyard, maintenance building, and visitors' building is obtained through a 6-inch main from the city of Bristol Water Department.

The treated water supply at the powerhouse has a maximum inlet pressure of 222 pounds per square inch. A pressure reducing station in the powerhouse reduces the water pressure to 50 pounds per square inch for use in the powerhouse and for supplying two lawn sprinklers adjacent to the powerhouse.

A 2-inch treated water supply header continues at unreduced pressure to the basement of the visitors' building, at which point the pressure is reduced to 55 pounds per square inch for use at the visitors' building.

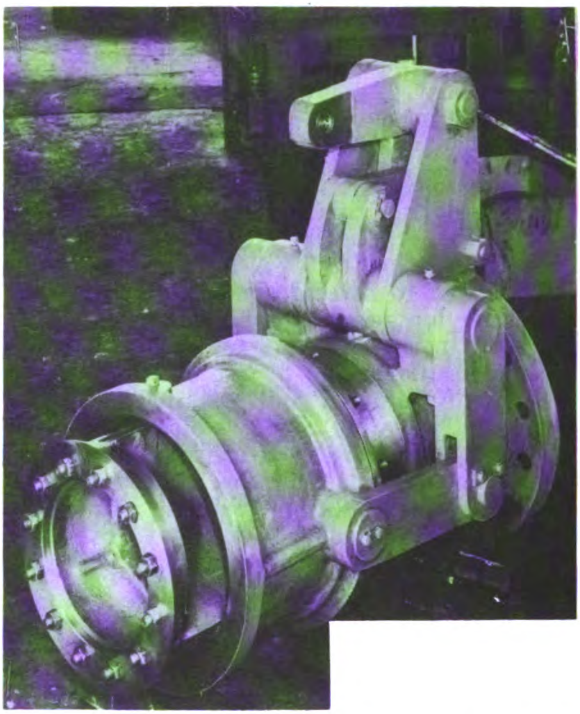


FIGURE 125.—*12-inch Howell-Bunger regulating valve for raw water supply to city of Bristol, Tenn., from South Holston Dam.*

A pressure reducing valve outside the maintenance building reduces the water pressure to 125 pounds per square inch for use at that building.

The fire hydrants at the switchyard are provided with throttling valves on the individual hose connections to reduce the water pressure to whatever pressure can be safely handled whenever hose lines are used.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 540-gallon concrete septic tank 4 feet south of the building. The effluent from the tank discharges into a perforated 4-inch pipe laid in filter material under the riprap of the tailrace.

The waste from the toilet facilities in the visitors' toilet building on the north bank discharges into a 2,000-gallon concrete septic tank approximately 70 feet southwest of the building. The effluent from the tank discharges into a 6-inch perforated pipe laid in crushed stone under the riprap at elevation 1758.75.

The waste from the toilet facilities in the maintenance building discharges into a 540-gallon concrete septic tank 10 feet east of the building. The effluent from the tank discharges into a subsurface tile field.

Drainage and unwatering

Drainage from the intake chamber access, which is also the visitors' building basement, is pumped to headwater. An 18-inch diameter by 24-inch-deep sump is serviced by one 3,500-gallon-per-hour sump pump. All drainage from the intake chamber and access tunnel flows by gravity, through two 8-inch drain lines, to the tailrace.

The sluiceway tower roof and the stair hatch cover frame drain directly to headwater. All sluiceway tower drainage below maximum headwater elevation flows by gravity to the sluiceway discharge tunnel.

All powerhouse drainage above maximum tailwater elevation flows to the tailrace. Drainage below this elevation flows to the station sump, which is located below the elevation 1502.5 floor in the electrical bay. The station drainage and unwatering sump has a capacity of approximately 10,780 gallons and is serviced by one 340-gallon-per-minute, vertical, turbine-type pump discharging directly to the tailrace, for normal station drainage. The pump is operated automatically by float switch controls.

An unwatering system for the draft tube and scroll case is used to permit inspection and repair of the underwater parts. The penstock is equipped with a screened outlet and a 10-inch drain line with shutoff valve. When the butterfly valve is closed, the water in the penstock and scroll case drains through the wicket gates and the opened valve in the 10-inch drain line into the draft tube. A suitable air valve is provided to prevent collapse of the exposed penstock in the intake chamber. The draft tube is equipped with a screened outlet 12 inches above the low point of the draft tube. A 12-inch drain pipe, with shutoff valve, connects the draft tube to the station sump.

One 2,500-gallon-per-minute, vertical, turbine-type pump is operated manually during unwatering periods and discharges directly into the tailrace at a point approximately 165 feet downstream from the end of the draft tube. The unwatering pump is operated normally by float switch control and is used to augment the station drainage pump capacity. An alarm sounds in the Watauga control building to notify operators that the unwatering pump is operating. Provision has been made for the ultimate installation of a second unwatering pump, if required.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is provided for protection of the generator, the oil storage room, and the oil purification room in the powerhouse. The system includes three banks of 50-pound cylinders, consisting of an initial and a reserve bank of 12 cylinders each and an 8-cylinder delayed discharge bank. The initial bank is arranged for simultaneous discharge of all 12 cylinders to the nozzles in the generator housing. The delayed bank provides intermittent release of 8 cylinders to maintain a sufficient concentration. The reserve bank is arranged with interconnecting piping and controls to function in the same manner as the initial bank. The reserve bank is normally set to release all 12 cylinders to the oil storage room or to release 6 cylinders to the oil purifica-

tion room. Pressure-operated trips close fire doors and ventilation dampers to these rooms when the system is activated.

Numerous hand-type carbon-dioxide extinguishers are available throughout the powerhouse. Portable wheel-type carbon-dioxide extinguishers are provided in the fire equipment buildings, of which there are one each in the transformer yard and switchyard.

General fire protection in the powerhouse, switchyard, transformer yard, visitors' building, and maintenance building is furnished by hose connections supplied from the treated water system. Four 1½-inch fire hose outlets in the powerhouse, and one each in the visitors' building and in a combination hose and hydrant house near the maintenance building, are each equipped with a valve, 75 feet of unlined linen hose, hose rack, and an adjustable nozzle.

The two fire equipment buildings for protection of electrical equipment in the switchyard and transformer yard each contain a fire hose cart, complete with wrenches, reel, two 50-foot lengths of hose, and two atomizing hose nozzles. One 4-inch fire hydrant is in the transformer yard and one in the switchyard.

Service equipment

The machine shop, adjacent to the erection area of the powerhouse generator room, is equipped with only the smaller machines required for routine maintenance, as listed in table 14, page 626. Any repair work requiring larger machine tools is to be made in the Watauga powerhouse machine shop.

An automatic pushbutton-controlled electric elevator is installed for the use of operating personnel in the sluiceway tower. The total lift is from the top to the bottom landings, a distance of 196.8 feet, with no intermediate landings. The elevator has a rated live load capacity of 1,200 pounds at a car speed of 100 feet per minute. Design data covering this machine are included in table 6, page 394.

Heating and ventilating

The powerhouse, intake, and visitors' buildings are mechanically ventilated for the removal of heat from electrical equipment or solar radiation, for the relief of dampness, and for the comfort and safety of the occupants. Electric unit heaters strategically located throughout these buildings and the sluiceway tower heat rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters and conveniently located plug receptacles supplement the permanently connected heaters as required.

Air entering the intake chamber is dehumidified by the circulation of cool lake water through cooling coils located in the air supply. Dampers in the basement of the visitors' building are designed to automatically open wide allowing large quantities of outside air to the intake chamber during penstock and unit unwatering, when pressure within the intake chamber access is reduced by exhausting air through the penstock valve.

The combined capacities of the heating and ventilating systems are as follows:

Cubic feet per minute of air supplied and exhausted	49,100
Kilowatts of installed electric heating	249

HALES BAR

The Hales Bar project is on the Tennessee River at river mile 431.1, a distance of 33 miles downstream from Chattanooga and 39.9 miles downstream from Chickamauga Dam. The original hydro plant was built by the Chattanooga and Tennessee River Electric Power Co. during the years 1905 and 1913 and acquired by TVA on August 15, 1939, from the Tennessee Electric Power Co. At that time the hydro plant generating facilities consisted of 14 units with a total rated generating capacity of 50,483 kilowatts. Unit 9 was later rewound by TVA, which raised the plant capacity to 51,100 kilowatts. In addition to the powerhouse, the project as acquired by TVA included a navigation lock at the right side of the river, and a straight overfall spillway in the river channel. Also acquired by TVA was a 40,000-kilowatt capacity steam plant located downstream from the left embankment.

The initial step in a series of improvements of the project was the installation of a cutoff wall to arrest leakage under the dam which represented a considerable loss of energy and was endangering the safety of the dam. Following completion of the cutoff wall, the adjustment of the reservoir level was begun to improve navigation above the dam to the site of Chickamauga Dam. Piers and gates were installed in the spillway to raise the minimum headwater from elevation 626.25 to elevation 632. The spillway was shortened from an original length of 1,200 feet to an overall length of 788 feet to allow space for an additional lock and extension of the powerhouse. The spillway crest was lowered to compensate for the flood discharge capacity lost by the change in length, and 17 gate openings were provided with radial gates, 40 feet wide by 19 feet high with their top at elevation 635. The reservoir level is varied between elevations 632 and 634.

With the construction of Chickamauga Dam to provide stream flow regulation, it was desirable to increase the discharge capacity of the Hales Bar turbines to approximately equal that of Chickamauga, since the useful storage in the Hales Bar pool is very limited. This was accomplished by the addition of two new units with a maximum discharge capacity of about 22,000 cubic feet per second. The addition of units 15 and 16 increased the capacity of the hydro generating station to 99,700 kilowatts. Authorization, operation, and cost data are as follows:

Authorization (units 15 and 16)	June 28, 1949
Commercial operation:	
Units 1 to 10	1913
Units 13 and 14	1915
Units 11 and 12	1916
Unit 15	July 11, 1952
Unit 16	December 23, 1952
Cost of the 16-unit project (acquired cost to TVA plus cost of TVA improvements), including switchyard	$35,613,604

The completed project with the powerhouse extension is shown in figure 126, and the general plan, elevation, and sections of the project are shown in figure 127. Additions and improvements to the power facilities included, in addition to the powerhouse extension, new transformers and switching equipment; a new control building to provide central control of the old and new hydro units, steam plant,

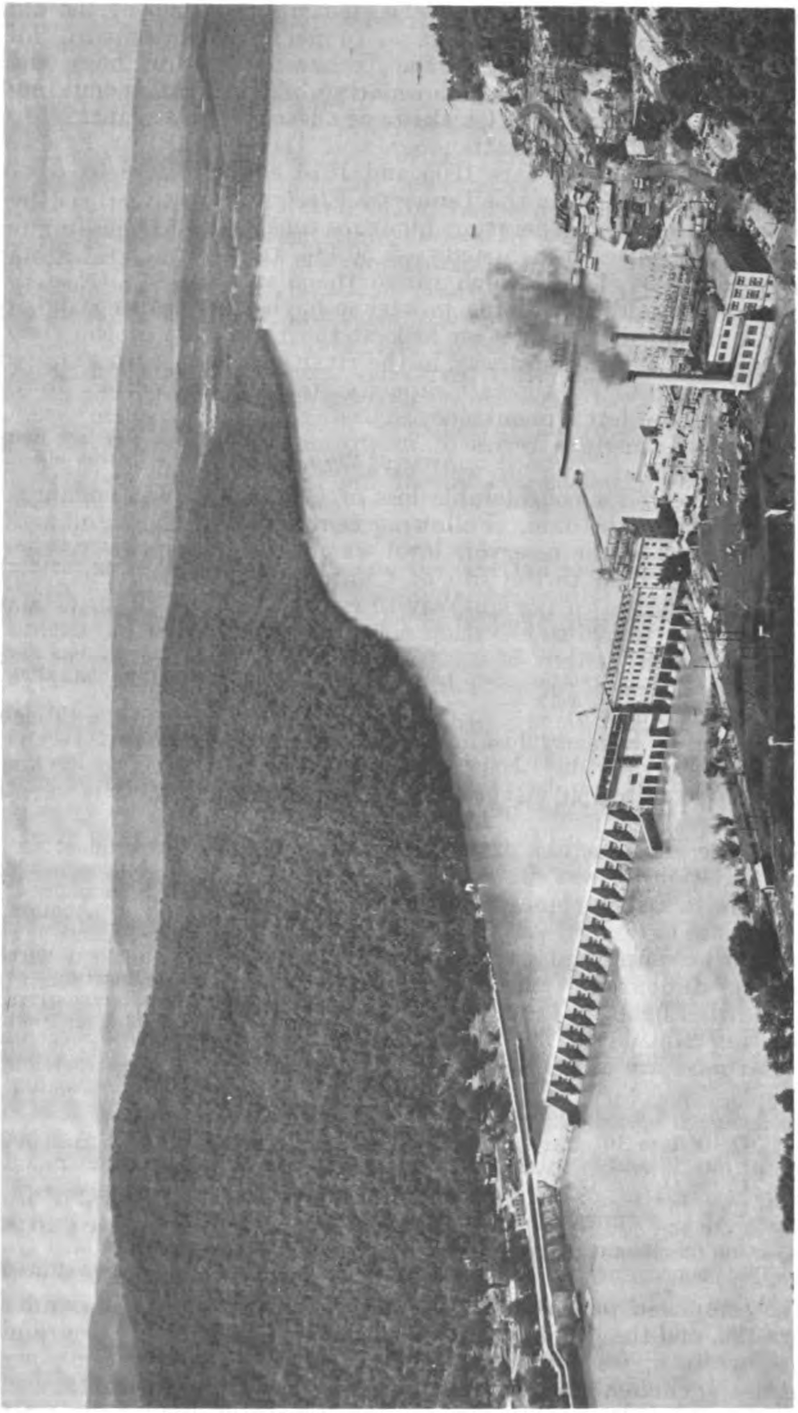


FIGURE 126.—*Hales Bar project—steam plant at lower right.*

and switchyards; improvement in the ventilation system of the old hydro plant; a new leads and cable tunnel; new switchyard fill upstream from the left embankment; a new intake for the screen house of the steam plant; a new insulating oil purification building in the yard; and numerous alterations of the old hydro plant.

Turbines

The first 14 units are the vertical Francis type manufactured by the S. Morgan Smith Co. The following description of these units is taken from a discussion by George A. Jessop of "Modernization of the Hales Bar Plant," by Adolf A. Meyer, in *American Society of Civil Engineers, Transactions*, volume 120, pages 559–562, dated 1955:

Originally the plant contained 10 triple runner units, two in each of five bays. Each unit consisted of two 72-inch "standard" wheels, one discharging downward and one upward to balance the thrust, and one 63-inch "standard" wheel mounted above the pair and used as a "booster" when the head was low and the flow ample * * *. The rated capacity of the two lower wheels was about 4950 horsepower at 37-foot head.

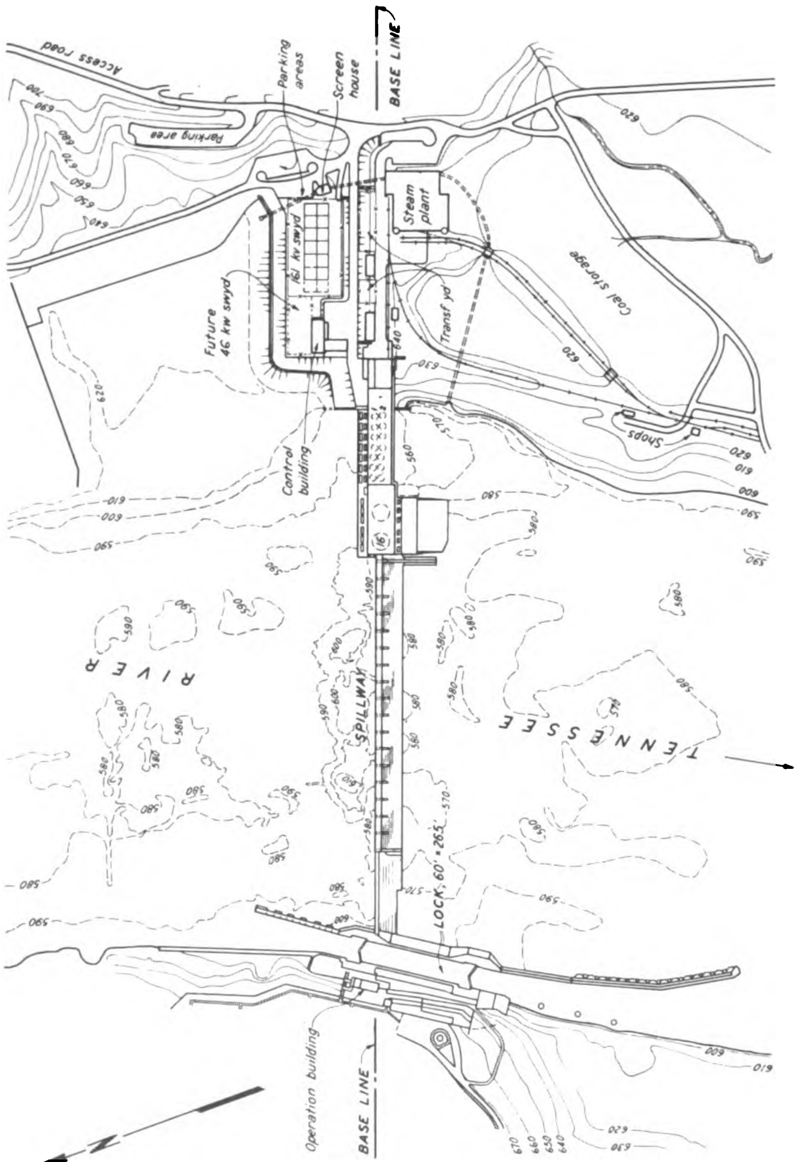
In 1915 and 1916 six units of single runner, vertical wheels, each in a concrete spiral case and with concrete elbow draft tube, two units in each of three flumes, were installed. The two units are necessarily on the same transverse centerline, but are on different longitudinal centerlines, one being further downstream than the other. The upstream wheel is set low and the downstream wheel high so that the spiral cases and draft tubes are separate and distinct water passages. Two of these turbines replaced two of the original triplex turbines and used the old generators operating at 112.5 revolutions per minute. The other four units were placed in two unused bays and had 100-revolution-per-minute generators.

These turbines are essentially modern in design and construction with efficiencies that compare favorably with the best that can be obtained today in new power plants. The rated horsepower, however, is 4150 at 37-foot head, a substantial reduction from the capacity of the original units. The size of these turbines was limited by the width of the bays as originally built.

* * * * * * *

In 1925 a program was initiated to replace the eight remaining original turbines with ones having better mechanical construction, higher efficiency and all the capacity that could be installed on the existing discharge passages or draft tubes. To this end, more efficient runners were used and distributors, or wheel cases, had solid cast iron stay rings, gates with integral stems supported in bronze bushed sockets in the head covers and bottom rings, with levers keyed to the upper end of the stems and with links connecting the levers to the gate operating rings. These distributors, although submerged, had essentially "outside type," or modern, gate operating mechanisms thus eliminating the original "inside type" mechanisms. Internal flanges on the draft tubes were cut out in the field so that runners with the largest possible discharge diameter and greatest capacity could be installed. The rated output of the two lower wheels was increased to about 5530 horsepower.

In 1952 TVA completed the installation of two Kaplan-type turbines in a portion of the old spillway section of the dam. These turbines were manufactured by the S. Morgan Smith Co. and are identical to the Guntersville units. Each is direct-connected to a 27,000-kilovolt-ampere synchronous generator. These turbines are rated 34,000 horsepower each at 36-foot head and operate at a speed of 69.2 revolutions per minute. They are designed to operate under any head from a maximum of 40 feet to a minimum of 15 feet and to withstand a maximum runaway speed of 189 revolutions per minute. At rated conditions the value of specific speed is 145, and the centerline of the runner is set approximately 6 feet below normal tailwater elevation, giving a plant sigma of 1.09.


Access road
Parking areas
Screen house
BASE LINE
Parking area
Steam plant
161 kv swyd
Future 46 kw swyd
Coal storage
Transf yd
Control building
Shops
SPILLWAY
RIVER
TENNESSEE
LOCK, 60' x 265'
Operation building
BASE LINE
N

PLAN

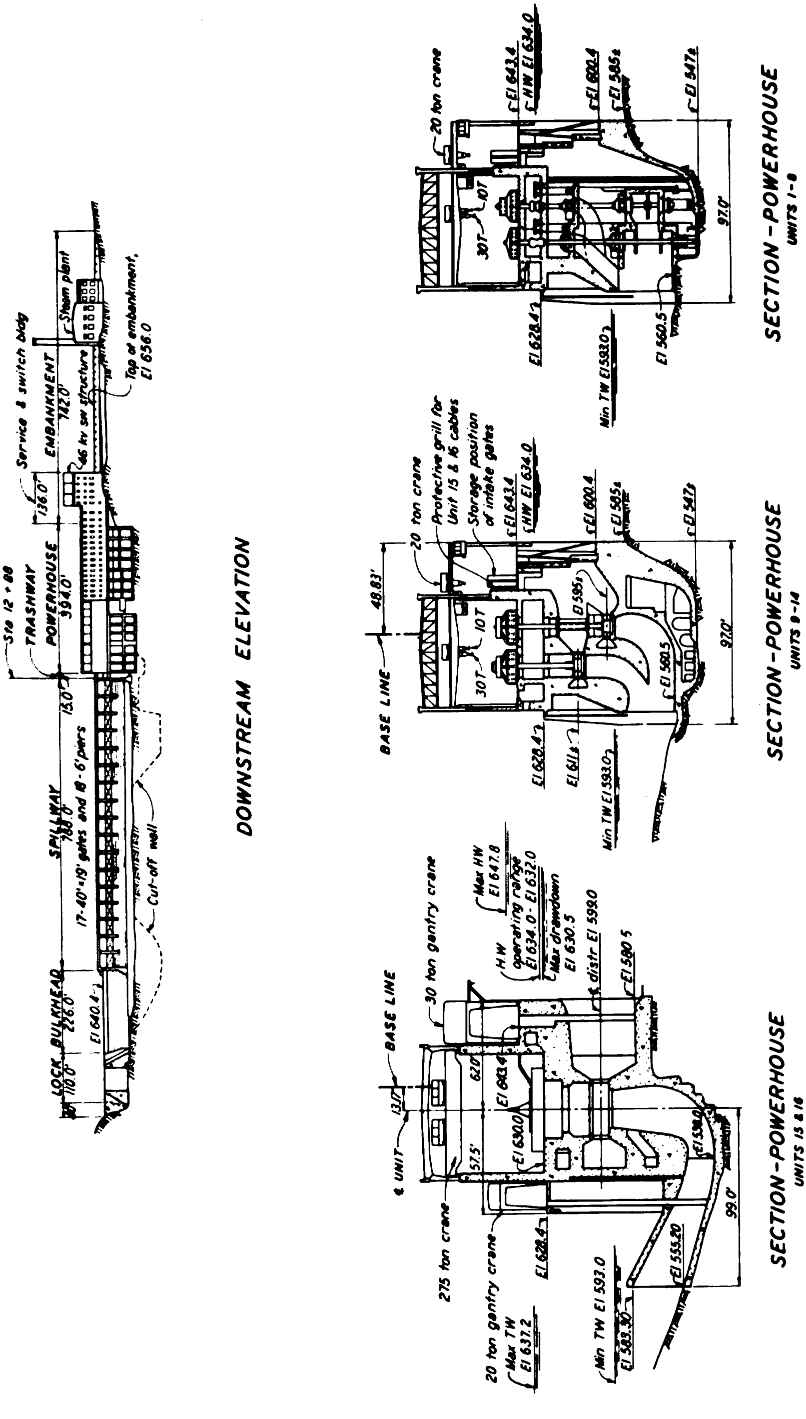


FIGURE 127.—*Hales Bar—plan, elevation, and sections.*

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Units 15 and 16 have concrete spiral cases and stay rings which are fabricated of welded steel plate. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts, and the hydraulic thrust. The runners each have five cast-steel blades set in a cast-steel hub which contains the blade operating mechanism. Certain areas on the discharge side of each blade are prewelded with stainless steel to prevent pitting due to cavitation. A hydraulic cylinder located at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt. The shaft is guided by a water lubricated guide bearing of molded plastic, or Insurok, material located in the bore of the head cover barrel.

A section through the powerhouse extension at one of the new units is shown in figure 128.

Governors

The governors for units 15 and 16 are the twin cabinet-actuator type manufactured by the Woodward Governor Co. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the control room. The oil pumps are the herringbone gear type each with a capacity of 250 gallons per minute at 300 pounds per square inch and are driven by 60-horsepower motors. The oil pressure systems are interconnected so that both governors may be operated from one pump if necessary. The twin sump tank is located in the base of the cabinet and has a volume of 280 cubic feet. The pressure tanks are located directly behind the actuator cabinet, and each has a volume of 311 cubic feet.

Generators

The generators of the 14 units in the old powerhouse are open frame, vertical shaft, air-cooled machines, manufactured by the General Electric Co. Units 1 to 10 are rated 3,750 kilovolt-amperes, 3,750 kilowatts, 1.0 power factor, 6,600 volts, and operate at 112.5 revolutions per minute. Units 11 to 14 are rated 4,250 kilovolt-amperes, 3,400 kilowatts, 0.8 power factor, 6,600 volts, and operate at 100 revolutions per minute. A view of the generator room with the original units in the foreground is shown in figure 129.

The generators of units 15 and 16, also manufactured by the General Electric Co., are enclosed, water-cooled, vertical shaft units. These generators are rated 27,000 kilovolt-amperes, 24,300 kilowatts, 0.9 power factor, 13,800 volts, 3 phase, 60 cycles and operate at 69.2 revolutions per minute. They are each equipped with 12 water-cooled heat exchangers within the air housing, through which the air is circulated. A General Electric type thrust and segmental guide bearing is below the rotor and immersed in an oil reservoir with a capacity of 2,000 gallons. Cooling coils in the generators bearing oil reservoir are designed for a flow of 100 gallons per minute with 30 degree centigrade water temperature.

The generators of units 15 and 16 are each equipped with four combination brakes and jacks which are mounted on the main arms of the lower bearing bracket and four additional jacks mounted on

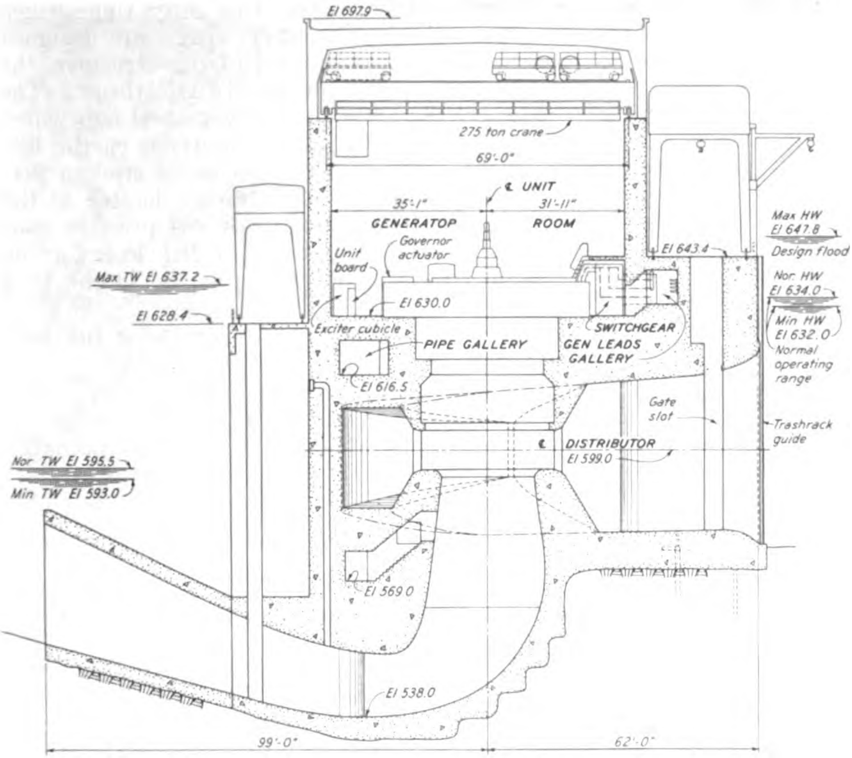


Figure 128.—*Hales Bar units 15 and 16—powerhouse section.*

the sidearms which bear against the brake ring on the underside of the rotor rim. Compressed air at 100-pound-per-square-inch pressure is supplied for braking from the station compressed air system and is automatically controlled. Oil pressure for jacking is applied at 1,200 pounds per square inch by a portable hand-operated oil pump.

Generator fire protection is provided by a low-pressure carbon-dioxide fire-extinguishing system. A view of the generator room with the new units in the foreground is shown in figure 130.

Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are on the elevation 615.37 floor of the service bay, which is between the old powerhouse and unit 15. The storage facilities consist of 1 clean- and 1 dirty-oil tank, each of 3,300-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of about 38-gallon-per-minute capacity. The system includes a purifier of 350-gallon-per-hour capacity. A complete piping system supplies and returns oil for the governor system and generating bearings of units 15 and 16. The system is arranged to prevent mixing of clean and dirty oil.

The insulating oil pumps and purification equipment are in the oil purification building in the yard with storage tanks adjacent. The storage facilities consist of one 13,700-gallon clean insulating

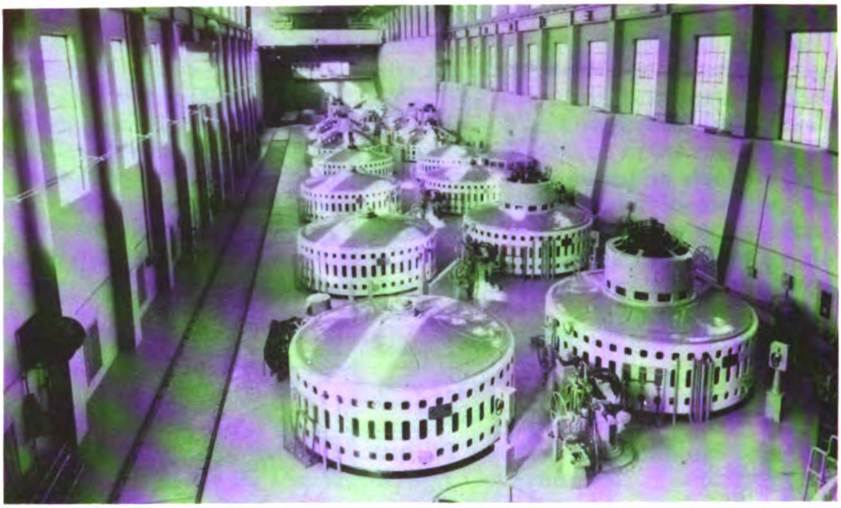


FIGURE 129.—*Hales Bar generator room with fourteen original units in foreground.*

oil tank, one 13,700-gallon dirty transformer oil tank, and one 7,050-gallon dirty circuit breaker oil tank. The pumping equipment consists of one 120-gallon-per-minute clean oil pump and one 122-gallon-per-minute dirty oil pump. The system includes a purifier with filter press, providing a purifying capacity of 600 gallons per hour without the press or 900 gallons per hour with the press. A complete insulating oil piping system transfers oil as required. Supply and return lines are provided to the main transformer bank 4 and station service transformers in the service and switch building of the powerhouse and to conveniently located valve boxes in the transformer yard and switchyard. Connections between the outdoor electrical equipment and the piping system are made with flexible hose through 3-inch drain and 1½-inch fill connections. The system is arranged to prevent mixing of clean and dirty oil.

A permanent pipe header for filling and draining the runner hub oil of units 15 and 16 is installed in the draft tube access gallery. Hose connections are provided for the use of a portable pump and portable storage tanks.

Compressed air systems

A complete piping system with service outlets distributes compressed air throughout the powerhouse, to the generator brakes, and to the intake and draft tube decks. An air compressor and receivers in the service and switch building supply the system at 100 pounds per square inch. The system includes a new 98-cubic-foot air receiver and control equipment for automatic operation.

Provision has been made for the future installation of a draft tube evacuation air system if required.

The governor compressed air system for units 15 and 16 is supplied by a 9.4-cubic-foot-per-minute air compressor with a discharge pressure of 300 pounds per square inch. The compressor receiver is direct-connected to the governor pressure tanks. The pressure is frequently checked, and the air supply replenished as required.

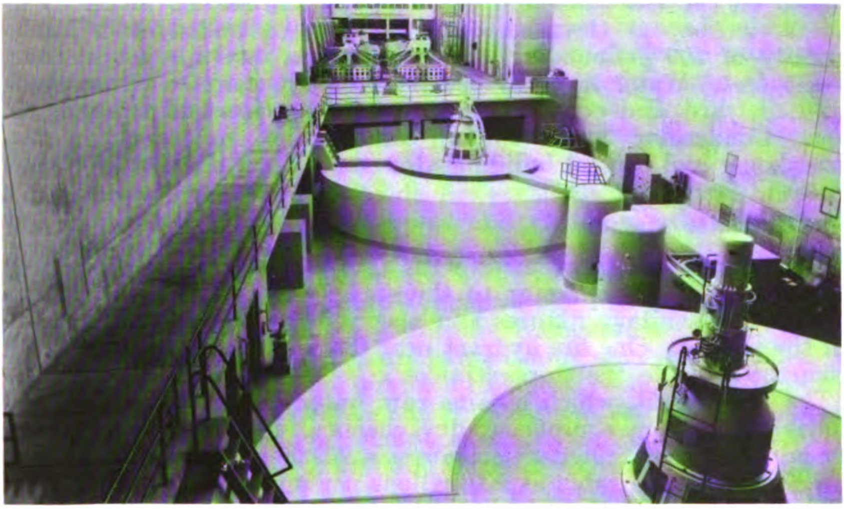


FIGURE 130.—*Hales Bar generator room with new units 15 and 16 in foreground.*

Raw water system

The raw water system provides water for cooling and lubrication of units 15 and 16, station services, fire protection, and other miscellaneous services. A raw water intake in the scroll case of units 15 and 16 supplies unit cooling requirements. The water passes through a strainer and is then pumped to the generator air coolers, the generator bearing oil coolers, and through a separate strainer to the turbine bearing. Provision is also made for obtaining turbine bearing water by gravity from the scroll case intake, bypassing the pump and main strainer. Each unit cooling water pump is rated at 1,300 gallons per minute against a total discharge head of 50 feet and is started or stopped by manual remote control from the control building when the unit is started or stopped. An emergency cooling water pump, located in the service bay and drawing water from a forebay intake, is a permanent standby for each unit pump. It is rated at 1,300 gallons per minute against a total discharge head of 60 feet, and is started or stopped by push button on the actuator panel. Each unit normally supplies its own water, but the system is so arranged that water may be supplied from any other unit as well as from the emergency line.

Flow through the generator air coolers is automatically controlled by a motor-operated thermostatically controlled proportioning valve actuated by a feeler bulb in the generator housing.

The raw water supply to the unit has its own series of alarm circuits operated by flowmeters to indicate low flows. The flowmeters in the supply lines to the generator bearing oil coolers and turbine bearing have an additional electric contact to shut down or prevent starting the unit on low flow.

Raw water for fire protection and station services is obtained from the forebay and pumped into a 50,000-gallon storage tank

located on the left embankment. The fire and service pump is in the service bay at elevation 615.37, is float-controlled, and has a capacity of 500 gallons per minute against a total discharge head of 245 feet. Water flows by gravity from the tank to the control building, yard, and powerhouse for station services and fire protection. Condensing water for air-conditioning equipment in the powerhouse and control building also comes from the storage tank.

Treated water system

A treated water filter plant with a capacity of 125 gallons per minute supplies feed water to the steam plant and, in addition, supplies the sanitary fixtures and several lawn sprinklers throughout the project. One fire hydrant near the filter plant obtains water from the main to the storage tanks.

The filter plant, which obtains raw water from the forebay, includes coagulation equipment, dry chemical feeders, a 125-gallon-per-minute gravity filter, chlorinators, a 20,000-gallon clearwell, and two service pumps rated at 200 gallons per minute each.

Three elevated storage tanks with a total capacity of 23,000 gallons provide a maximum static pressure of about 75 pounds per square inch in the system.

Sewage disposal

The waste from the toilet fixtures in the steam plant and water-treatment plant discharges into a 540-gallon concrete septic tank approximately 200 feet south of the steam plant on the east side of the coal storage area. The effluent from the tank discharges into a subsurface tile field.

The waste from the toilet facilities in the powerhouse, control building, and bath house discharges into a 2,970-gallon concrete septic tank 116 feet south of the baseline on the east bank of the tailrace. The effluent from the tank discharges into a subsurface tile field.

Drainage and unwatering

Powerhouse roof and deck drainage is piped directly to tailwater or to the forebay, whichever is most convenient. All other powerhouse drainage is piped to the station sump, which is in the basement of the service bay adjacent to unit 15. It is serviced by two 300-gallon-per-minute, turbine-type pumps discharging directly to tailwater. The pumps are automatically operated by float switch control.

It was necessary to provide means for unwatering the draft tubes and scroll cases of units 15 and 16 to allow access to the turbine because the runner is below normal tailwater. The draft tubes for these units were therefore provided with a screened outlet 15 inches above the low point of the draft tube. A 16-inch drain line with a shutoff valve connects each draft tube to the station sump. The scroll case and draft tube of each unit are also connected to each other and to tailwater by a 16-inch line.

Two 5,400-gallon-per-minute, deepwell, turbine-type pumps are provided for unwatering the sump. These are manually controlled and may be used to supplement the station drainage pumps. A high water alarm signals the operator if the flow into the sump exceeds the capacity of the drainage pumps.

Fire protection

A low-pressure carbon-dioxide fire-extinguishing system protects the generators and various rooms and enclosures throughout the powerhouse where fire hazards exist. A 4-ton refrigerated carbon-dioxide storage tank supplies the system at about 300-pound-per-square-inch pressure. Figure 270, chapter 13, "Fire Protection," page 561, shows a view of this low-pressure refrigerated system. Automatic flooding by means of a discharge timing device is provided for the rheostat room, station service switchgear room, the 6.6-kilovolt switchgear room, oil pumping and reactor room, station service transformer room, and enclosed transformer bank 4. Prolonged discharge of carbon dioxide with initial and delayed applications is automatically supplied to either unit 15 or 16 generator housing. Manual application of carbon dioxide from hose reels is available for protection of the open frame type units 1 to 14.

A high-pressure carbon-dioxide fire-extinguishing system containing four 50-pound cylinders is provided for automatic release into the purification room of the oil purification building in the yard.

Portable dry chemical hand extinguishers are located in the powerhouse and control building. One 150-pound wheel-type dry chemical fire extinguisher is stored in the oil purification building for use in the transformer yard and switchyard.

General fire protection in the powerhouse, control building, transformer yard, and switchyard is available from fire hose outlets or fire hydrants in the raw water distribution system. Numerous fire hose outlets in the powerhouse and control building are equipped with a valve, 75 feet of unlined linen hose on a rack, and a nozzle. One fire hose cart, complete with wrenches, reel, 100 feet of hose, and two nozzles, is stored in the oil purification building for yard use.

Service equipment

The machine shop is in the powerhouse service and switch building in space originally occupied by three main transformer banks, which were relocated in the switchyard during the installation of generating units 15 and 16. The machine shop is of conventional size and is equipped with machine tools provided for the original plant installation supplemented by replacement equipment subsequently purchased.

Heating, ventilating, and air conditioning

Air conditioning is provided for the control room, communications room and lobby of the control building, and for the assembly room and offices of the service and switch building. The powerhouse and the remainder of the control, switch, and service buildings are mechanically ventilated. Electric unit heaters throughout the buildings furnish heat to rooms or areas where occupancy may be expected. Portable electric heaters serve to supplement the permanently connected heaters as required.

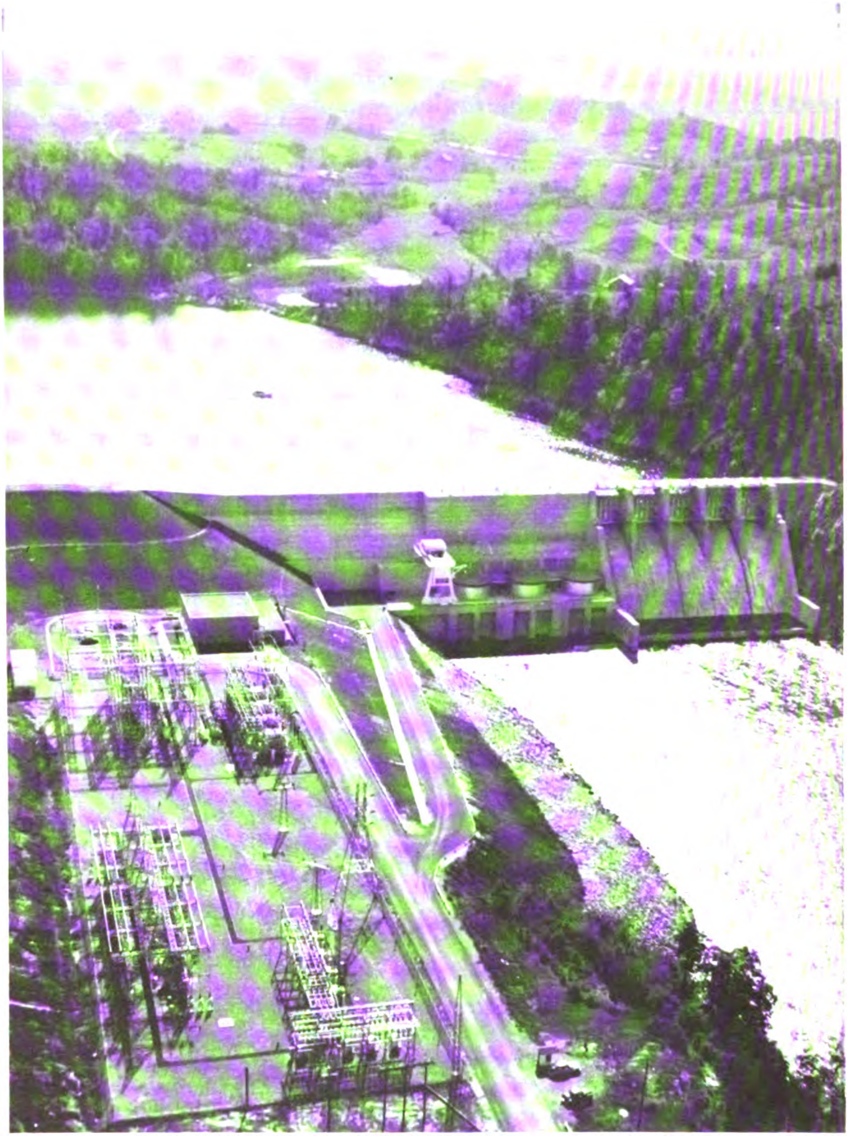


FIGURE 131.—*Boone project.*

The air-conditioned spaces are served by combination heating, cooling, and ventilating systems each with fan, refrigerant compressor, water-cooled condenser, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the mechanical refrigeration plant for the control building and by self-contained, packaged air-conditioning units for the service and switch building.

The combined capacities of the heating, ventilating, and air-conditioning systems are as follows:

Cubic feet per minute of air supplied and exhausted	629,440
Kilowatts of installed electric heating	270
Horsepower of refrigeration	55

BOONE

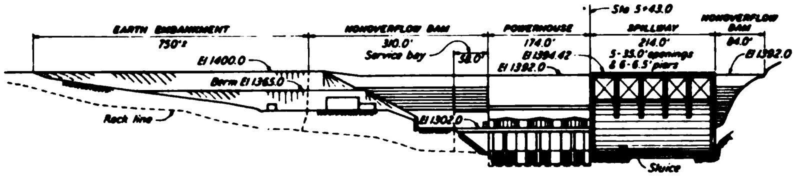
Boone Dam is on the South Fork Holston River at mile 18.6 in eastern Tennessee approximately 1.4 miles below the confluence with the Watauga River. The project is a combined power and flood control type, contributing a capacity of 75,000 kilowatts from the three generating units and providing a useful controlled storage volume of 150,000 acre-feet. Authorization, construction, operation, and cost data are as follows:

Authorization	August 25, 1950
Construction started	August 29, 1950
Dam closure	December 16, 1952
Commercial operation:	
Unit 3	March 16, 1953
Unit 2	June 12, 1953
Unit 1	September 3, 1953
Cost of the 3-unit project, including switchyard	$27,101,737

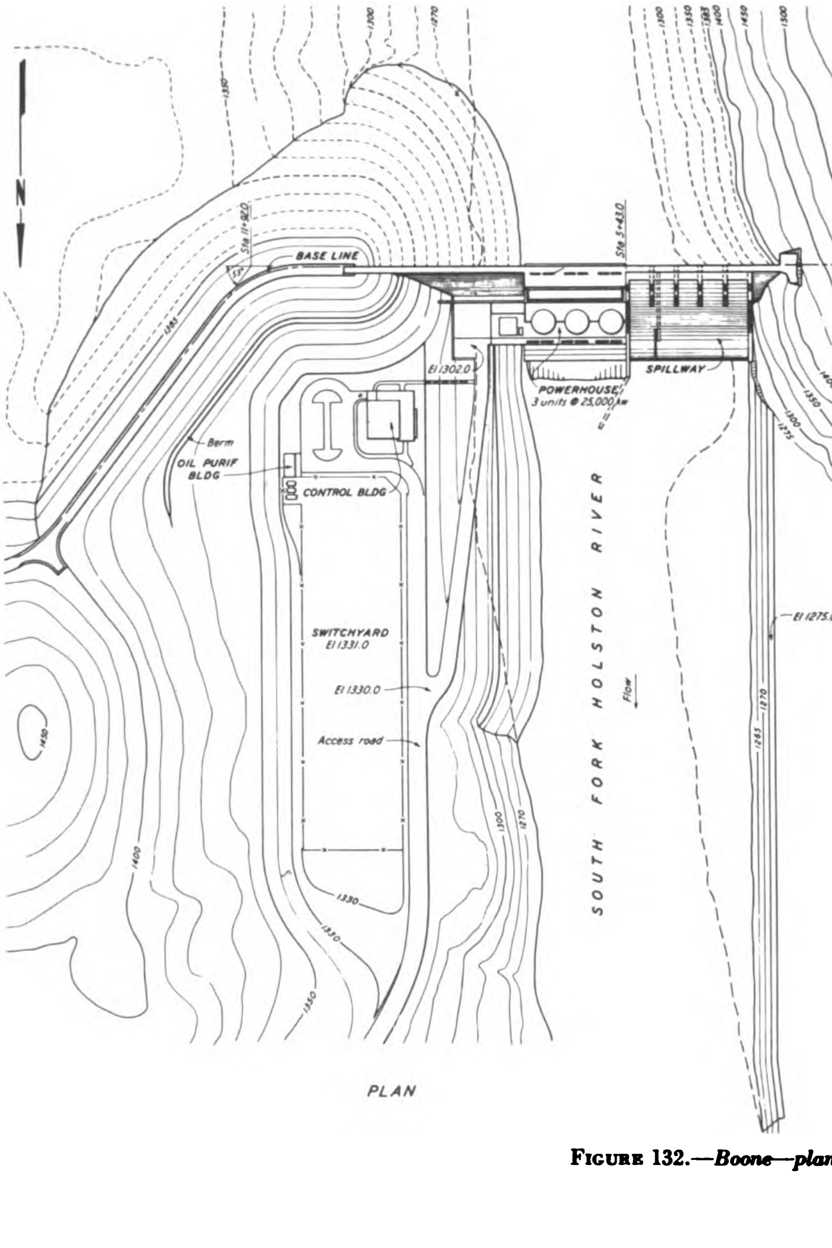
A view of the Boone project, including all the main features except the visitor's building, is shown in figure 131. As indicated in the general layout (fig. 132), the main features of the dam include a small concrete nonoverflow section at the left abutment, an ogee-type spillway containing five bays, an intake and powerhouse, a longer concrete gravity nonoverflow dam, and a curved earth fill embankment extending to the right abutment. The crest length of the dam is approximately 1,532 feet. The control building and switchyard with an adjacent oil purification building are located downstream from the dam on the right bank.

The spillway contains five 35- by 35-foot radial gates which are operated by fixed hoists on the spillway deck. It is designed for a maximum flow of 137,000 cubic feet per second. A bucket-shaped apron dissipates the energy in the river channel below the spillway. A low level outlet through the spillway section is provided by a 5.67- by 10-foot sluice which also discharges into the apron and adds a maximum capacity of 3,830 cubic feet per second to supply the minimum discharge required downstream when the power units are shut down. Two hydraulically operated slide gates are installed for closure of the sluice.

The intake and the powerhouse are constructed as a monolithic, gravity-type structure consisting of three blocks, each 58 feet wide by 160 feet long. The intake deck accommodates the intake gate fixed hoists and an 11-foot roadway. Two waterways in each block supply water to the concrete scroll case.

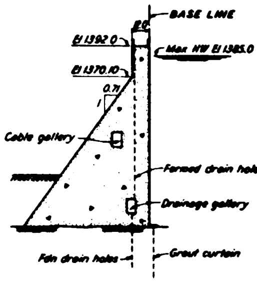


DOWNSTREAM ELEVATION

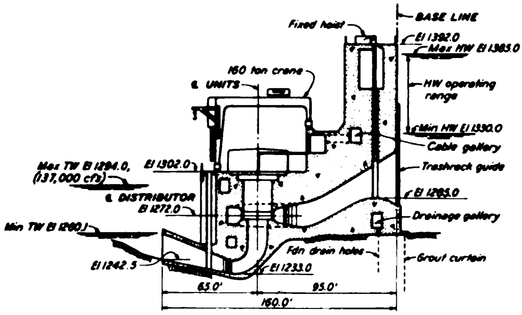


PLAN

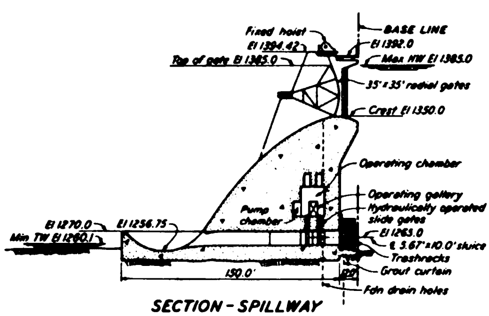
Figure 132.—*Boone—plan,*



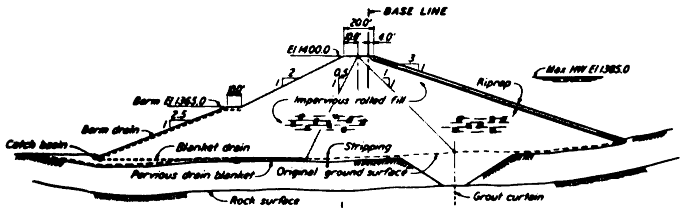
SECTION - NONOVERFLOW DAM



SECTION - POWERHOUSE



SECTION - SPILLWAY



SECTION - EARTH EMBANKMENT

elevation, and sections.

An outdoor-type powerhouse (figs. 133 and 134) was constructed with the generator and draft tube deck 8 feet above maximum tailwater. The generators are provided with removable covers and the deck is roofed over from the centerline of the units to the intake. This space houses the governors and the various electrical boards. A pipe gallery and carbon dioxide and raw water equipment rooms are on the floor below the deck, and there is a draft tube access gallery downstream from the units above the elbow-type draft tube. A 160-ton gantry crane serves the powerhouse and service bay. The draft tube gates are handled with a jib-boom hoist on the crane (fig. 134).

The service bay is 58 feet wide adjacent to the powerhouse in the nonoverflow section. Two floors below the deck contain the erection space, machine shop, oil storage and purification room, the air compressor, and the station sump pumps. A two-story building adjacent to the upstream bulkhead provides space for an entrance lobby, storage, ventilation fans, and the toilets and lockers.

Turbines

Three vertical Francis-type hydraulic turbines furnished by the Newport News Shipbuilding & Dry Dock Co. are direct-connected to the generators (fig. 135). The turbines are rated 34,500 horsepower at a net head of 90 feet and operate at a speed of 100 revolu-

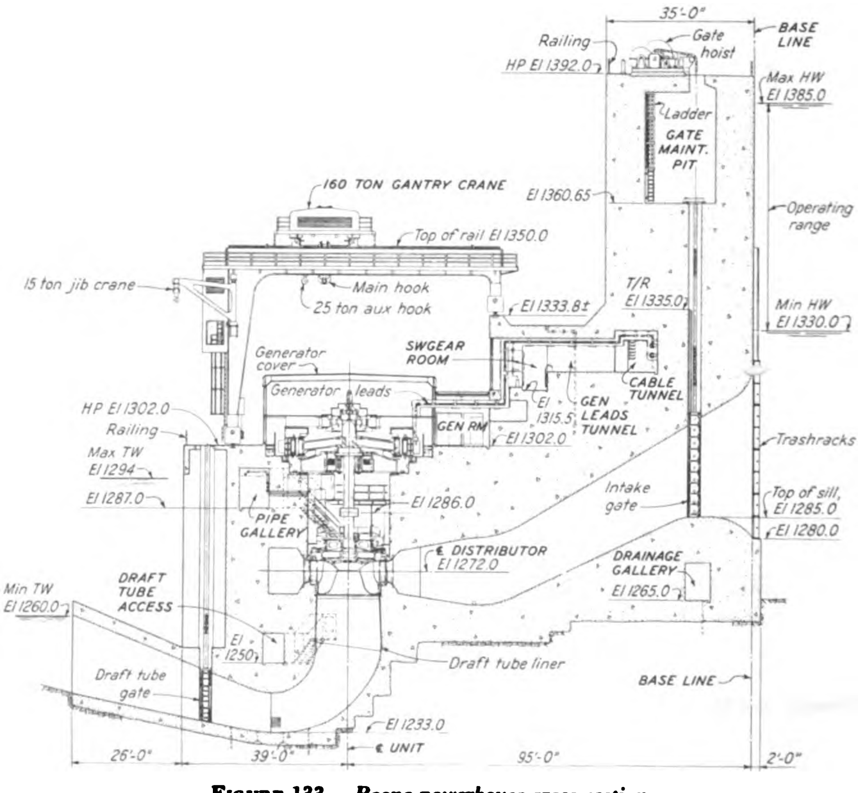


FIGURE 133.—*Boone powerhouse cross section.*

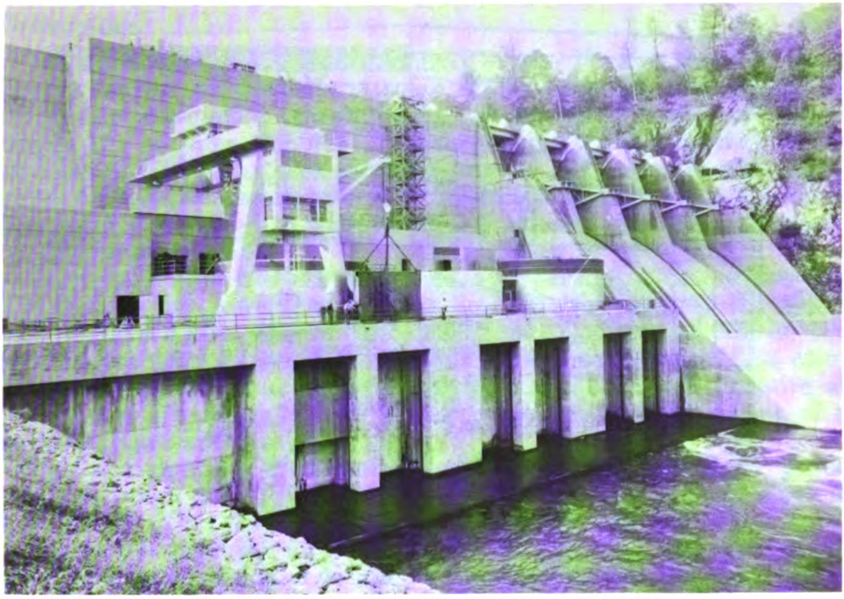


Figure 134.—*Boone project showing outdoor type powerhouse.*

tions per minute. They are designed to operate satisfactorily under any head from a minimum of 65 feet to a maximum of 123 feet and are most efficient at a head of about 110 feet. They are designed to withstand a maximum runaway speed of 189 revolutions per minute. At rated conditions the value of specific speed is 67, and the centerline of the runner is set approximately 4 feet above normal tailwater elevation, giving a plant sigma of 0.35.

These units have concrete spiral cases and cast steel stay rings. This is the highest head plant in the TVA system at which concrete spiral cases are used. The stay ring forms the main foundation ring of the turbine and the 12 stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. Because of the difficulty of obtaining castings of the required size at the time these units were built, the runners were cast in two sections and welded together. The completed runners were full-annealed after all welding had been completed. The turbine shaft is guided by a babbitt-lined, oil-lubricated bearing above the head cover. The oil is normally circulated by an alternating-current oil pump, and a direct-current pump comes into operation automatically in case the alternating-current pump fails to supply sufficient oil to the bearing. Specifications for the turbines and governors are included in appendix A, and an oak tree curve of these turbines is shown in plate 7.

Governors

The governors are the cabinet actuator type manufactured by the Woodward Governor Co. There is a single cabinet for unit 1, and a twin cabinet for units 2 and 3. Each governor is complete with

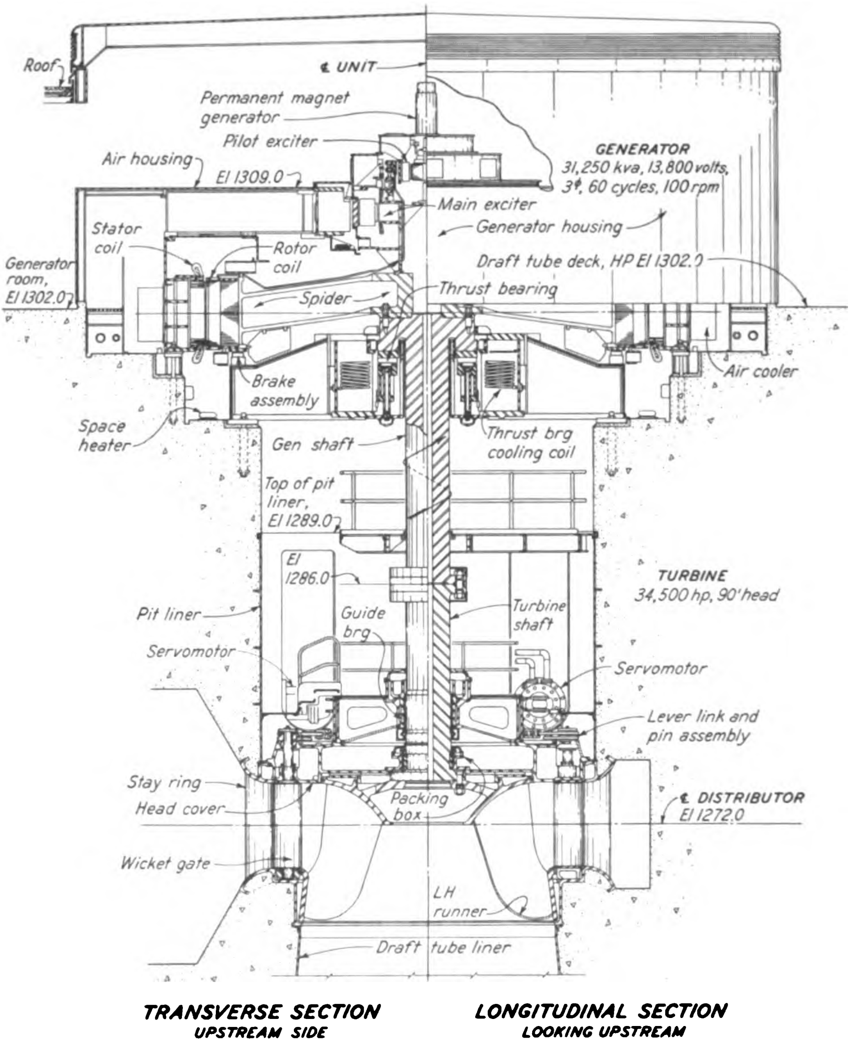


FIGURE 135.—*Boone powerhouse—section through turbine and generator.*

governor head, sump tank, pressure tank, oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the control building. The pressure systems for units 2 and 3 are interconnected so that both units may be operated from one oil pump if necessary. Unit 1 is provided with 2 oil pumps, 1 of which serves as a spare. The oil pumps are of the herringbone gear type each rated at 150 gallons per minute at 300 pounds per square inch. The sump tanks are in the base of the cabinets and the pressure tanks are immediately behind the cabinets. Each pressure tank has a volume of 110 cubic feet.

Generators

The three generators manufactured by the Westinghouse Electric Corp., are the vertical-shaft type, totally enclosed, and cooled by forced-air circulation through six water-cooled heat exchangers within the housing (fig. 135). Each generator has a normal rating of 31,250 kilovolt-amperes, 25,000 kilowatts, 0.8 power factor, 13,800 volts, 3 phase, 60 cycles, and operates at 100 revolutions per minute. The rotor is designed to withstand all overloads and runaway speeds of 1.89 times normal.

Each generator has six combined air-operated jacks, which are mounted on the lower bearing bracket and bear against the brake ring on the under side of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system and is automatically controlled. Oil pressure at 2,000 pounds per square inch for jacking is applied by means of a portable hand-operated oil pump.

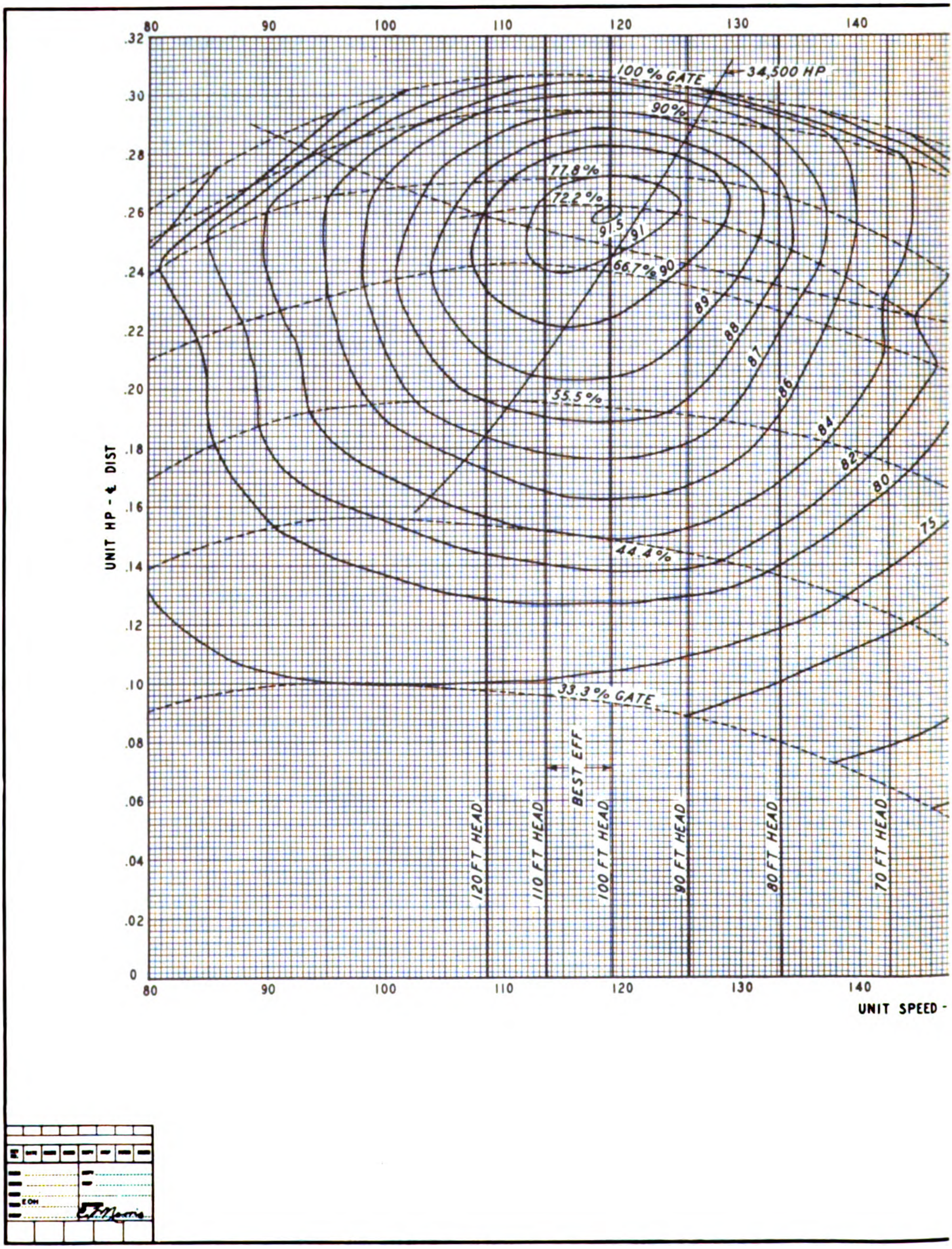
The combination Kingsbury-type thrust and segmental guide bearing, which is designed for a maximum load of 430 tons, is below the rotor. The guide bearing is the segmental, babbitted type, capable of adjustment as to diameter and center. The bearings are immersed in oil which is cooled by water circulated through copper coils immersed in the oil reservoir.

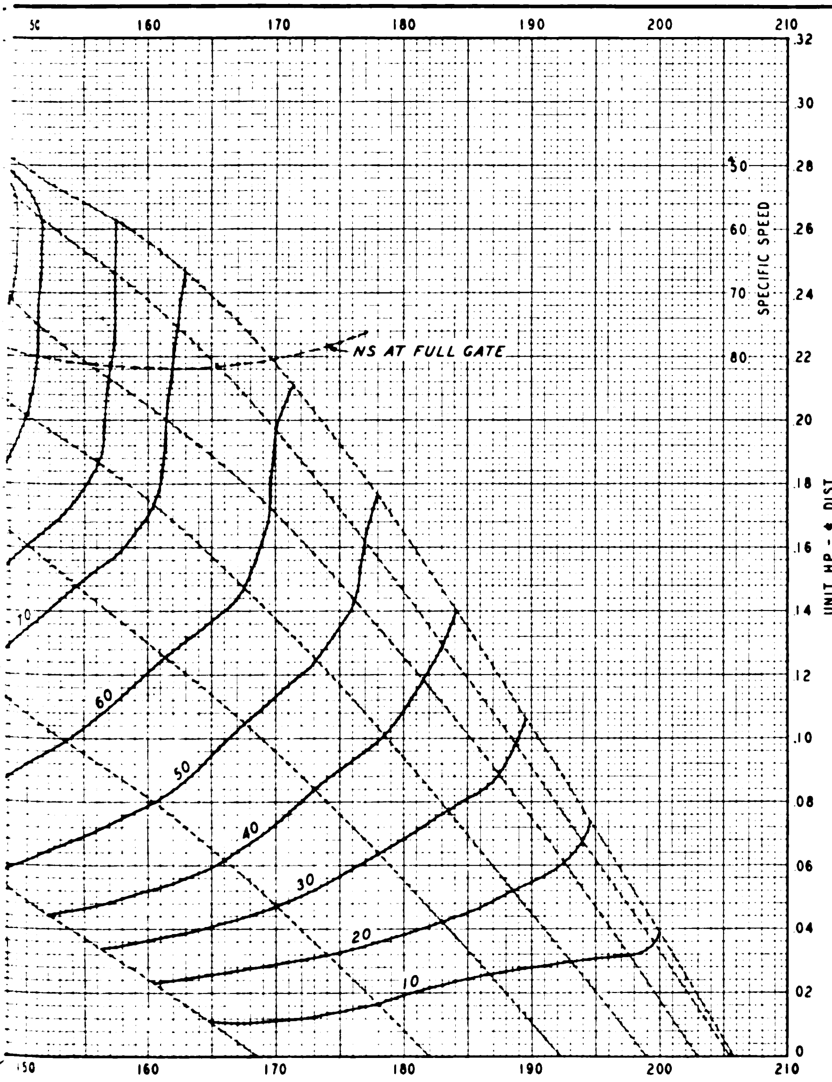
Generator fire protection is provided by an automatic carbon dioxide fire extinguishing system, discharging through nozzles, located in ring headers above rotor.

Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are in the basement of the powerhouse service bay. The storage facilities consist of 1 clean- and 1 dirty-oil tank, each of 2,125-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 33.5-gallon-per-minute capacity. A stationary purifier of 375-gallon-per-hour capacity is provided. Specifications for the lubricating and insulating oil purifiers are included in appendix B. A complete piping system supplies and returns lubricating oil to the generator guide and thrust bearings, turbine guide bearings, and governor oil systems. The turbine bearing oil circulating system includes an alternating-current pump, with a direct-current pump for emergency service.

The insulating oil pumping and purification equipment is located in the oil purification building adjacent to the south end of the switchyard, and the storage tanks are located adjacent to this building. The storage facilities consist of 1 clean-oil tank of 11,600-gallon capacity, 1 dirty transformer oil tank of 11,600-gallon capacity, 1 dirty circuit breaker oil tank of 7,050-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 100-gallon-per-minute capacity. A purifier of 600-gallon-per-hour capacity is provided. A complete piping system has supply and return lines to the oil-insulated electrical equipment in the switchyard. All connections between the electrical equipment and the piping system are made with flexible hose through 2-inch drain and 1½-inch fill connections in conveniently located valve boxes. The system is designed to prevent mixing of clean and dirty oil.


100 % GATE
34,500 HP
90%
77.8%
72.2%
91.5
91
66.7%
90
89
88
87
86
84
82
80
75
55.5%
44.4%
33.3% GATE
BEST EFF
120 FT HEAD
110 FT HEAD
100 FT HEAD
90 FT HEAD
80 FT HEAD
70 FT HEAD
UNIT HP - ℄ DIST
UNIT SPEED -



NOTES

Runner test curves reduced to 1.0 ft dia at 1.0 ft head for 32.75" RH Runner #135 (37.25")
Curves based on Holyoke test No 3073 Newport News Shipbuilding & Dry Dock Co. Newport News, Va Nov 29-30, 1926 (16 13.5"-49") 0934
32.75 = ℄ dist dia
37.25 = disch dia
Ratio = 1.375

POWERHOUSE

OAK TREE CURVES OF FRANCIS RUNNER # 135 UNDER 1' HEAD FOR 12" DIA

BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
C. F. Norris	H. Petersen	R. A. Monroe
KNOXVILLE	9-20-50 31 M 4	47K900 R

The two sluice gates, which serve as the service and emergency gates in the sluiceway, are raised and lowered by means of hydraulic cylinders above the bonnet of each valve. Oil pressure for operation of the gates is supplied by a 20-gallon-per-minute pump with a discharge pressure of 1,200 pounds per square inch. Specifications for this pump are included in appendix B. The pump, together with a 330-gallon oil storage tank, is located in the pump chamber of the spillway operating gallery. A complete piping system conveys oil to and from the cylinders.

Compressed air systems

A complete piping system distributes compressed air throughout the powerhouse, to the draft tube and intake decks, and, by means of an underground connecting supply header, throughout the control building. The generator air brakes and numerous service outlets are supplied from the system. A stationary, single-stage, double-acting air compressor, with a capacity of 111.5 cubic feet per minute and a discharge pressure of 100 pounds per square inch, is located in the basement of the powerhouse service bay. The system includes a 200-cubic-foot air receiver, water-cooled aftercooler, and control equipment for automatic operation.

A portable, air-cooled, single-stage, electric-motor-driven air compressor of 105-cubic-foot-per-minute capacity and 100-pound-per-square-inch discharge pressure is available for general service where required.

Compressed air for the governor system is supplied by a stationary, 2-stage, air-cooled, electric-motor-driven compressor with a capacity of 9 cubic feet per minute and a discharge pressure of 300 pounds per square inch. The compressor is complete with receiver and controls for automatic operation.

Raw water system

There are two separate raw water systems, one supplying unit cooling and lubrication and the other supplying station services, fire protection, and other miscellaneous services.

An intake in each unit scroll case normally supplies water by gravity flow through a twin strainer to the generator air coolers, generator bearing oil cooling coils, and the turbine bearing packing box and upper runner seals. Each unit raw water system is interconnected for emergency supply from an adjacent unit.

A motor-operated gate valve serves as a complete shut-off of all water to the unit. This valve is opened or closed by manual remote control from the control building when the unit is started or stopped. Flow through the generator air coolers is controlled automatically by a motor-operated thermostatically controlled proportioning valve actuated by a thermometer bulb in the generator housing.

Flowmeters are provided in the three branch lines to each unit for annunciation to indicate low flow. The flowmeters in the generator bearing oil cooling water supply line and the turbine bearing packing box and runner seal water supply line have an additional electric contact to shut down or prevent starting the unit on low flow.

Raw water for fire protection and station services is obtained from an intake in the forebay. Strained water is discharged into

the distribution system by the fire and service pump located in the powerhouse service bay. The pump has a capacity of 188 gallons per minute and a total discharge head of 170 feet. It is operated automatically by float switch control in the 50,000-gallon storage tank located on the right abutment. The system provides fire protection from fire hose connections and hydrants for the switchyard, control building, and powerhouse by gravity flow from the storage tank. Cooling water for the air compressor and aftercooler, raw water supply for service outlets in the powerhouse, intake and draft tube decks, and the control building and supply for the lawn sprinklers in the switchyard and control building area are furnished from this system.

A pump house on the right abutment near the storage tank contains a raw water booster pump with a capacity of 37 gallons per minute and a total discharge head of 100 feet. This pump provides pressure for use of lawn sprinklers in the area of the visitors' building and right embankment.

Cooling water for the air-conditioning equipment and raw water for the water-treatment plant in the control building are normally obtained from intakes in the forebay by gravity flow. However, during periods of low headwater an emergency connection supplies these requirements from the 50,000-gallon storage tank.

Treated water system

Treated water for use in the control building, powerhouse, visitors' building, oil purification building, and maintenance building is supplied from the filter plant in the basement of the control building. Raw water supply is normally obtained from 1 of 4 intakes in the forebay or, during periods of low headwater, from the fire and service storage tank. The filter plant consists of five chemical solution feeders, including one spare, for injection of hypochlorite, calgon, alum, and soda ash solutions; a combined mixing and settling tank; two rapid sand gravity filters with a maximum capacity of 6.3 gallons per minute each; a clearwell with a working capacity of 740 gallons; a wash water storage tank; two 35-gallon-per-minute service pumps; and a storage tank with a working capacity of 448 gallons in the basement of the visitors' building. The entire plant is designed for automatic operation but may be operated manually. Operating instructions for this plant are included in appendix E.

A concrete storage tank in the basement of the visitors' building provides a static head for all sanitary fixtures and service outlets other than those at the visitors' building, which are supplied from the treated water booster pump adjacent to the tank. The booster pump delivers water from the storage tank to a steel pressure tank having a working capacity of 28 gallons. A pressure of 50 pounds per square inch is maintained by a pressure switch mounted on the tank. Plumbing fixtures in the visitors' building are served from this pressure tank.

Sewage disposal

The waste from the toilet facilities in the powerhouse and control building discharges into a 785-gallon concrete septic tank approximately 80 feet west of the control building. The effluent from the

tank discharges into a perforated 6-inch pipe laid in crushed rock under the riprap of the tailrace.

The waste from the toilet facilities in the visitors' building on the right embankment discharges into a 2,000-gallon concrete septic tank approximately 175 feet west of the building. The effluent from the tank discharges into a subsurface tile field.

The waste from the toilet facilities in the maintenance building discharges into a 540-gallon concrete septic tank located approximately 400 feet southwest of the building. The effluent from the tank discharges into a subsurface tile field.

Drainage and unwatering

All powerhouse drainage above maximum tailwater elevation is piped to the tailrace. Drainage below this elevation is piped to the station sump, which is located in the basement of the service bay. The station sump has a working capacity of about 16,000 gallons and is serviced by two 300-gallon-per-minute, turbine-type pumps discharging directly to the tailrace. The pumps are operated automatically by float switch controls.

An unwatering system for the draft tubes and scroll cases is used to permit inspection and repair of the underwater parts. Each scroll case is equipped with a screened outlet and a 12-inch drain line with shutoff valve. When the intake gate is closed the water in the scroll case drains to tailwater level through the opened valve in the 12-inch drain line into the draft tube. Each draft tube is equipped with a screened outlet 15 inches above the low point of the draft tube. A 12-inch drain pipe, with shutoff valve, connects each draft tube to the station sump.

Two 3,000-gallon-per-minute, vertical, turbine-type pumps operate during unwatering periods and discharge directly into the tailrace. The unwatering pumps are operated manually and may be used to augment the station drainage pumping capacity.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is used for protection of the generators and the lubricating oil storage and purification room in the powerhouse. The system consists of three banks of 50-pound cylinders—an initial bank and a reserve bank, each of 14 cylinders, and a reserve bank of 12 cylinders. The initial discharge bank is arranged for simultaneous release of all cylinders to any generator or to the lubricating oil storage and purification room. The reserve bank is arranged with interconnecting piping and controls to function as a substitute for the initial bank. The delayed bank provides intermittent release to maintain a sufficient concentration in the protected generator.

Automatic closing of a thermostat in the lubricating oil storage and purification room operates a time delay relay which provides immediate annunciation and delays the discharge of the initial bank for 20 seconds to allow time for personnel to leave the room. Pressure trips close dampers and release the fire door. Manual operation of the system is also provided.

There is a separate carbon-dioxide system in the insulating oil purification building in the switchyard. Four 50-pound carbon-dioxide cylinders are provided for protection of the oil purification room

in this building. The system is arranged for either manual or automatic release. Pressure switches stop operation of the oil pumps, exhaust fans, and electric heaters.

Raw water is supplied for general fire protection in the powerhouse, control building, and switchyard area. Numerous fire hose outlets in the powerhouse and control building are equipped with a valve, 75 feet of unlined linen hose on a rack, and a nozzle. Nine fire hydrants are provided in the switchyard and control building yard areas. A fire hose cart, complete with wrenches, reel, 100 feet of hose, and two nozzles, is stored in the oil purification building. One 100-pound, wheeled-type carbon dioxide extinguisher is also stored in this building for switchyard protection. Portable carbon-dioxide hand extinguishers are conveniently located in the powerhouse and control building.

Service equipment

The machine shop is in the transformer repair and rotor erection room in the powerhouse service bay, with the machines arranged along one wall. The shop is conventional size and includes equipment as listed in table 14, page 626.

Heating, ventilating, and air conditioning

Air conditioning is supplied for the control room, communications room, test rooms, lobby and offices of the control building. The remainder of the control building, the visitors' building and powerhouse are mechanically ventilated. Electric unit heaters throughout the buildings heat rooms or areas where occupancy may be expected. Portable electric heaters supplement the permanently connected heaters as required.

The air-conditioning spaces are served by three combination heating, cooling, and ventilating systems each with fan, electric blast heaters, cooling coils, humidifier, air filters, air distribution system, and controlling devices. Cooling and dehumidification are accomplished by the circulation of chilled water through the cooling coils by the water chilling mechanical refrigeration system. A self-contained, packaged air-conditioning unit serves the test rooms.

The combined capacities of the heating, ventilating, and air-conditioning systems are as follows:

Cubic feet per minute of air supplied and exhausted	106,400
Kilowatts of installed electric heating	359
Horsepower of refrigeration	45

FORT PATRICK HENRY

The Fort Patrick Henry Dam is in eastern Tennessee on the South Fork Holston River at mile 8.2 and a distance of 10.4 miles downstream from Boone Dam. The project is a single-purpose type for generation of power, contributing a rated generating capacity of 36,000 kilowatts from two units. With a fluctuation of only 5 feet in the reservoir level and a useful controlled storage volume of only 4,300 acre-feet, the station will utilize the upstream regulation provided by Watauga, South Holston, and Boone Dams for generation of power and will provide day-to-day regulation for downstream water use.

FIGURE 136.—*Fort Patrick Henry project.*

Because of the proximity of Boone and Fort Patrick Henry projects, forces from Boone were used for the construction of Fort Patrick Henry on an overlapping schedule which also permitted use of a large part of the same equipment on both projects. The authorization, construction, operation, and cost data of Fort Patrick Henry project are as follows:

Authorization	September 16, 1949
Construction started	May 14, 1951
Dam closure	October 27, 1953
Commercial operation:	
Unit 2	December 5, 1953
Unit 1	February 22, 1954
Cost of the 2-unit project, including switchyard	$12,395,668

A view of the project from the left bank is shown in figure 136. The principal features of the dam (fig. 137) include a small concrete nonoverflow section at the left abutment, a five-bay concrete spillway, the concrete intake and powerhouse, and a longer concrete nonoverflow dam to the right abutment. The control bay structure is on the downstream face of the dam adjacent to the powerhouse service bay. The transformer yard is at the toe of the nonoverflow section near the control bay, and the switchyard is farther downstream, extending along the right bank.

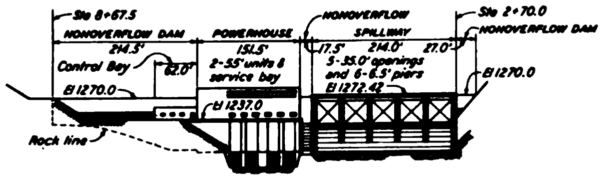
The indoor-type powerhouse consists of two unit bays and the service bay. The powerhouse intake is a reinforced concrete structure which provides waterways for the two units. The intake structure consists of two blocks, each 55 feet long. The intake gates are handled by a 20-ton gantry crane on the intake deck.

The powerhouse (fig. 138) consists of two 55-foot unit blocks and a 41.5-foot service bay block. A 125-ton overhead traveling crane is provided for erection and servicing of the units. One 12-ton electric monorail hoist is mounted on the outside of the downstream wall to handle the draft tube gates. The control bay structure is adjacent to the service bay and is 62 feet long.

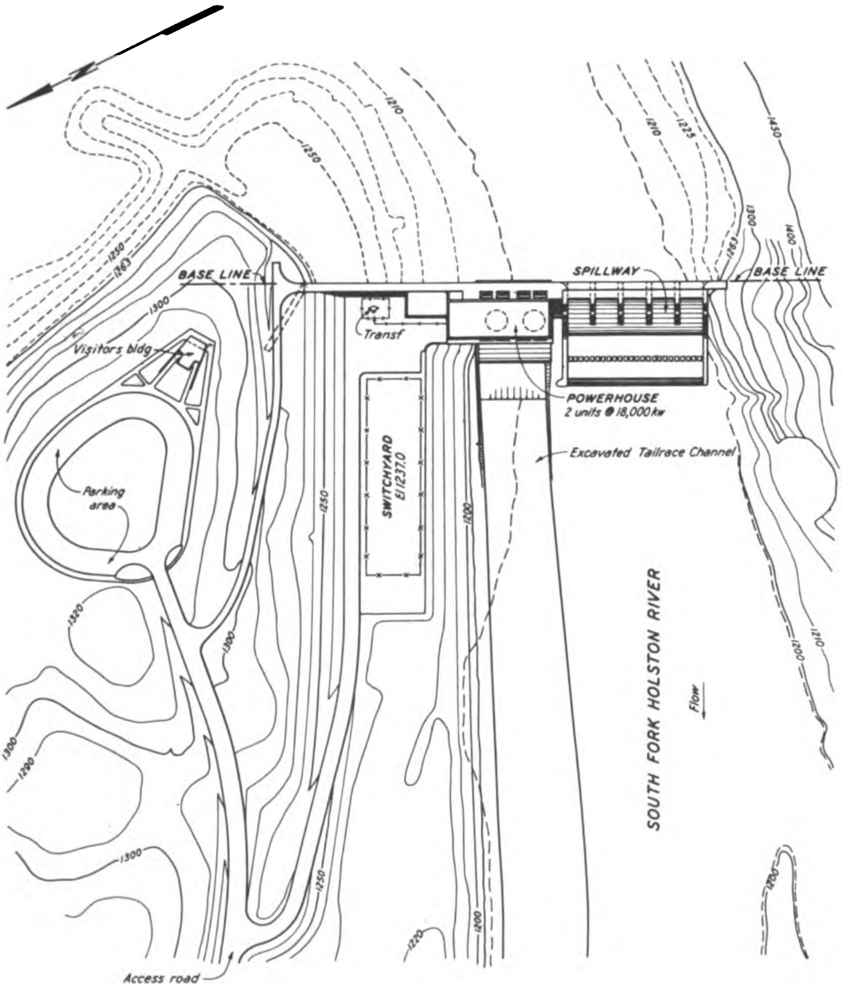
The spillway, which is designed for a maximum discharge of 141,000 cubic feet per second, is the ogee-type with the crest at elevation 1228. The top of the 35- by 35-foot radial gates is at elevation 1263. A fixed hoist on the spillway operating deck is provided for each of the five gates. The apron at the toe of the spillway contains a line of closely spaced baffle blocks for energy dissipation.

Turbines

Two Kaplan-type hydraulic turbines manufactured by the Newport News Shipbuilding & Drydock Co. are direct-connected to the generators. Each turbine is rated 25,000 horsepower at a net head of 61 feet and operates at a speed of 138.5 revolutions per minute. The turbines are designed to operate under any head from a minimum of 58 feet to a maximum of 75 feet with best efficiency occurring at approximately 67 feet. The turbines are also designed to withstand a maximum runaway speed of 319 revolutions per minute. At rated conditions the value of specific speed is 129, and the centerline of the runner is approximately 7 feet below normal tailwater elevation, resulting in a plant sigma of 0.78. Inspection of the runners after one year of operation showed that they met

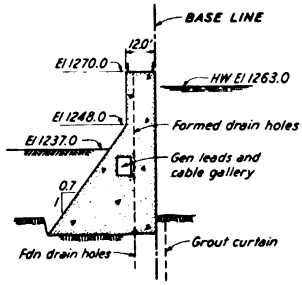


DOWNSTREAM ELEVATION

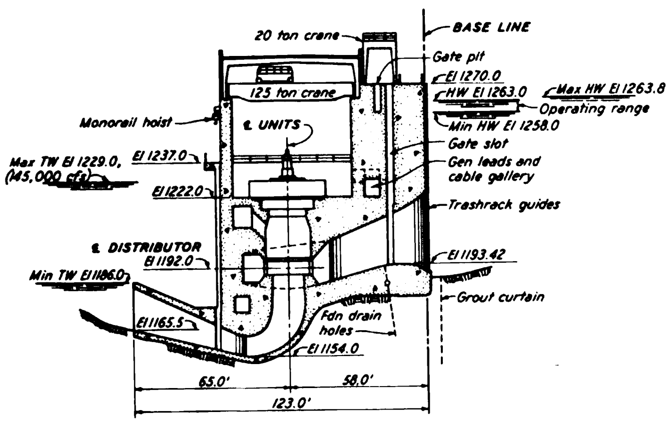


PLAN

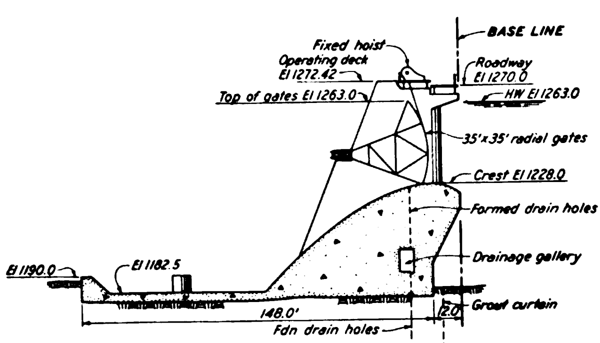
Figure 137.—*Fort Patrick Henry*—



SECTION - NONOVERFLOW DAM



SECTION - POWERHOUSE



SECTION - SPILLWAY

plan, elevation, and sections.

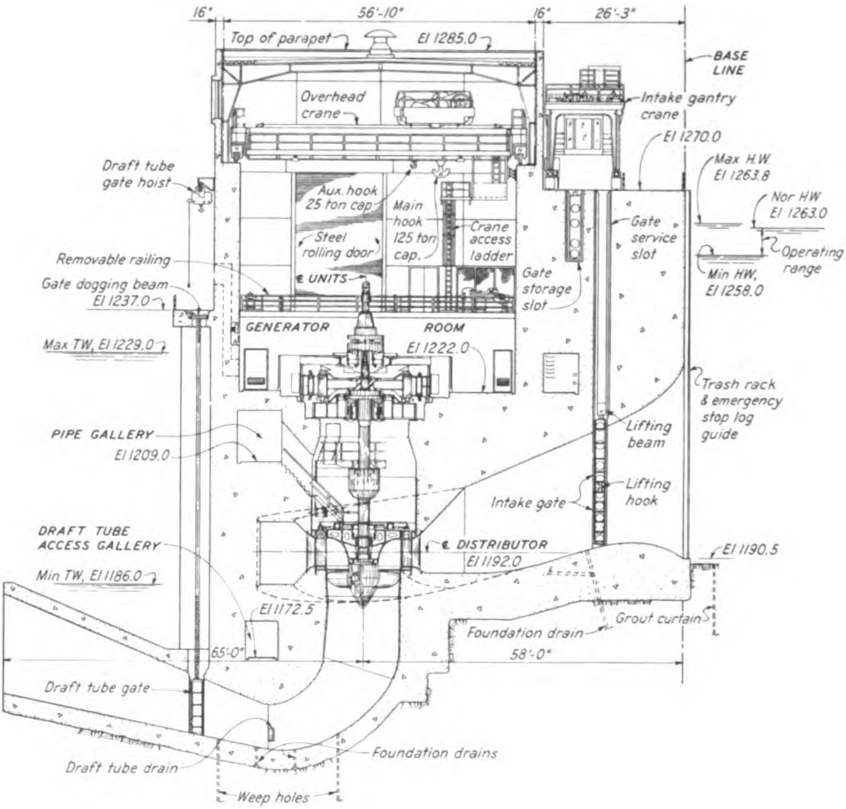


Figure 138.—*Fort Patrick Henry powerhouse section.*

the contract requirements for pitting due to cavitation; however, it was determined from the index tests that some cavitation does occur for full gate operation and low tailwater at 61-foot head. Sections of the turbine and generator are shown in figure 139.

The Fort Patrick Henry units have concrete spiral cases with cast steel stay rings. The stay rings are designed to support the weight of the superimposed building structure, the generator stator, the rotating parts and the hydraulic thrust. During preliminary model tests made by the manufacturer it was determined that a better flow pattern would be obtained by the use of additional stay vanes from the nosepiece to the upstream side of the stay ring; consequently, the vanes are spaced 15 degrees apart in this section and 30 degrees apart in the balance of the stay ring.

The runners each have six cast steel blades set in a cast steel hub. The hub contains the blade-operating mechanism which consists of an internal shaft and crosshead connected to the levers on each blade. The space inside the hub is filled with grease. Certain areas on the under side of each blade are prewelded with stainless steel placed where tests and experience have indicated that pitting is most likely to occur. A hydraulic cylinder at the top of the turbine shaft and operated by governor oil pressure controls the blade tilt.

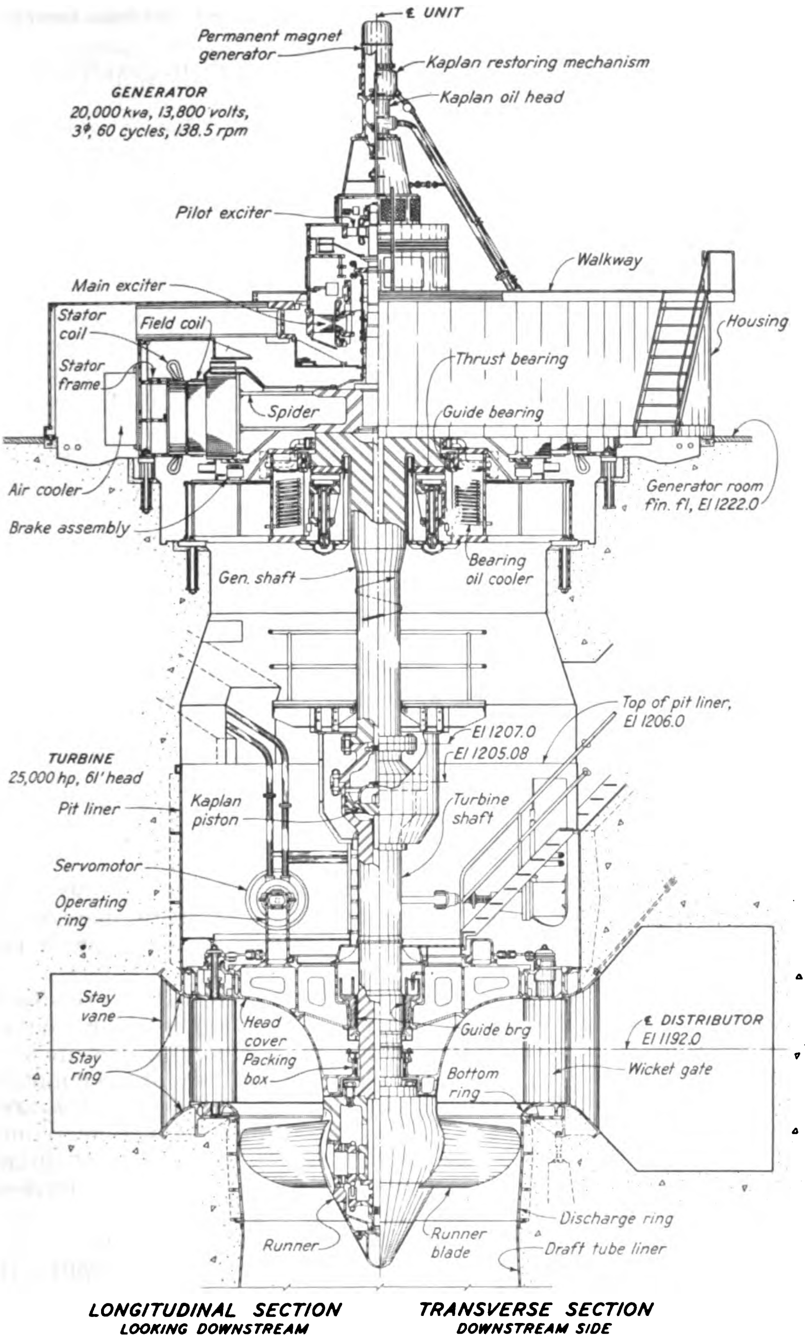


FIGURE 139.—*Fort Patrick Henry—turbine and generator sections.*

The turbine shaft is guided by an oil-lubricated babbitt bearing above the head cover.

Specifications for these Kaplan turbines and their governors are included in appendix A.

In accordance with the contract, efficiency and capacity tests were made on a homologous model in the hydraulic laboratory of the turbine manufacturer. These tests indicated that the turbines would exceed the efficiency guarantees by an average of about 1½ percent and would exceed the capacity guarantees at all heads.

Governors

The governors were manufactured by the Woodward Governor Co. and are of the twin-cabinet-actuator type. Each governor is complete with governor head, sump tank, pressure tank, oil pump, permanent magnet generator, and the necessary auxiliaries for remote control of the turbine from the Boone control room. The oil pumps are the herringbone-gear type with a capacity of 100 gallons per minute at 300 pounds per square inch and are driven by a 30-horsepower motor. The capacity of the pressure tank is 88 cubic feet, and the capacity of the twin sump tank is 370 cubic feet. The pressure systems of the two units are interconnected so that both governors may be operated from one oil pump.

Generators

The generators, manufactured by the Westinghouse Electric Corp., have a normal rating of 20,000 kilovolt-amperes, or 18,000 kilowatts continuous output at 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and operate at 138.5 revolutions per minute. The rotor is designed to withstand all overloads and runaway speeds of 2.35 times normal. The units are a vertical shaft type with totally enclosed generators which are cooled by air circulation through four water-cooled heat exchangers within each generator housing. The exciters are mounted on the upper bracket and are directly connected to the generator shaft. A Kaplan head and permanent magnet generator are mounted above the pilot exciter. A view of the completed generator room is shown in figure 140.

Six combination brakes and jacks are mounted on the lower bearing bracket and bear against the brake ring on the under side of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system and is automatically controlled. Oil pressure at 1,500 pounds per square inch for jacking is applied by a portable hand-operated oil pump.

The combination Kingsbury-type thrust and segmental guide bearing is below the rotor and is designed for a maximum load of 430 tons. The bearing is immersed in oil which is cooled by water circulated through coils immersed in the oil reservoir.

Circulation of cooling air through the generator is supplied by fans on the rotor, which force the hot air through the air coolers and over the top of the stator for recirculation. The air circulating system is sealed off at the bottom of the lower bearing bracket and at the top below the main exciter. Generator fire protection is provided by an automatic carbon dioxide fire extinguishing system, discharging through nozzles located in ring headers above the rotor.

Oil systems

The governor and lubricating oil storage tanks, pumps, and purification equipment are on the elevation 1207 floor of the service bay. The storage facilities consist of 1 clean-oil and 1 dirty-oil tank, each of 2,150-gallon capacity. The pumping equipment consists of 1 clean-oil and 1 dirty-oil pump, each of 36-gallon-per-minute capacity. Specifications for these oil pumping units are included in appendix B. The system includes a purifier of 350-gallon-per-hour capacity. A complete piping system supplies and returns oil for the governor system and the turbine and generator bearings from the purification and storage equipment. The system is arranged to prevent mixing of clean and dirty oil.

The insulating oil pumps and purification equipment are in the oil purification building in the switchyard with storage tanks adjacent. The storage facilities consist of one 5,165-gallon clean-insulating-oil tank, one 5,165-gallon dirty-transformer-oil tank, and one 1,850-gallon dirty circuit breaker oil tank, each mounted on concrete saddles outside the building. The pumping equipment in the oil purification room consists of 1 clean-oil and 1 dirty-oil pump, each of 56-gallon-per-minute capacity. The system includes a purifier with filter press, providing a purifying capacity of 600 gallons per hour without the press or 900 gallons per hour with the press. There is a complete insulating oil piping system. Supply and return lines are provided to conveniently locate valve boxes in the transformer yard and in the switchyard. Connections between the electrical equipment and the piping system are made with flexible hose through 2-inch drain and 1½-inch fill connections. The system is arranged to prevent mixing of clean and dirty oil.

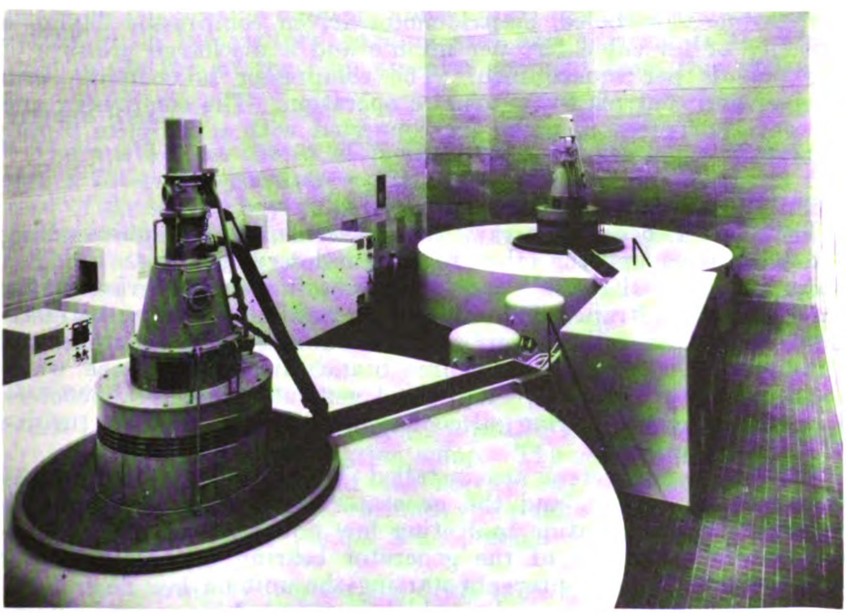


FIGURE 140.—*Fort Patrick Henry generator room.*

Compressed air systems

A complete piping system distributes compressed air throughout the powerhouse to service outlets and to the generator brakes. The generator brakes are automatically controlled by a small air brake valve mounted on the actuator. A stationary, single-stage, double-acting, electric-motor-driven air compressor is located in the powerhouse service bay. The compressor has a capacity of 111.4 cubic feet per minute and a discharge pressure of 100 pounds per square inch. The system includes a 50-cubic-foot air receiver and control equipment for automatic operation.

A portable, air-cooled, single-stage air compressor with a capacity of 105 cubic feet per minute and a discharge pressure of 100 pounds per square inch is also available for general service where required.

A separate compressed air system for draft tube evacuation depresses the water level in the draft tubes for operation of the units as synchronous condensers. Electrically controlled, air-operated valves controlled by switches on the governor cabinet and interlocked through gate position switches and the generator breaker automatically admit the air to the space under the head cover when the wicket gates are closed. When the water level has been depressed below the bottom of the runner, operation of the air valves are controlled by float switches to maintain this level. Three air receivers with a total volume of 1,050 cubic feet are in the basement of the service bay. The compressor, on the elevation 1222 floor of the service bay, is a stationary, single-stage, double-acting unit with a capacity of 342 cubic feet per minute and a discharge pressure of 100 pounds per square inch. The system includes a water-cooled aftercooler and control equipment for automatic operation of the compressor.

Compressed air for the governor system is supplied by a stationary, 2-stage, air-cooled, electric-motor-driven compressor having a capacity of 9.4 cubic feet per minute and a discharge pressure of 300 pounds per square inch. The compressor is complete with receiver and controls for automatic operation. The compressor and the governor pressure tanks are connected with a complete piping system.

Raw water system

There are two separate raw water systems, one for unit cooling and lubrication and the other for fire and service.

An intake in the scroll case of each unit provides gravity flow through a twin strainer for unit cooling and lubrication. An emergency cross connection supplies either unit from the intake and strainer of the other unit. Three branch lines supply the water requirements of each unit—1 to the 4 generator surface air coolers, 1 to the generator bearing oil coolers, and the other to the turbine bearing packing box.

Indicating flowmeters are installed in the supply lines to the generator air coolers and the generator bearing oil coolers with contacts for annunciation indicating low flow. An additional contact in the flowmeter of the generator bearing oil cooling water supply shuts down or prevents starting the unit on low flow.

A motor-operated gate valve, which is operated by manual remote control from the Boone control building, serves as a complete shut-

off for all water to the unit. Flow through the generator air coolers is controlled automatically by a motor-operated thermostatically controlled proportioning valve to maintain a proper temperature in the generator air housing.

Raw water for fire and service is obtained from the forebay and is pumped into a 25,000-gallon underground storage tank on the ridge near the right abutment. The fire and service pump, with a capacity of 150 gallons per minute, is float-controlled for filling the tank and is on the elevation 1222 floor of the service bay.

A fire booster pump furnishes sufficient pressure for fire-fighting purposes. The booster pump, with a capacity of 600 gallons per minute, is provided with a suction line from the 6-inch main to the 25,000-gallon storage tank and a check valve bypass for normal gravity flow. The pump is in the oil purification building in the switchyard and discharges into the fire and service distribution system. Fire hydrants in the switchyard, a fixed transformer sprinkler system, fire hose connections in the powerhouse and control bay, and numerous 1-inch service outlets in the powerhouse and on the intake and draft tube decks are supplied from this system.

Five lawn sprinklers adjacent to the powerhouse access road are supplied directly from the main to the 25,000-gallon storage tank. The cooling water supply to the aftercooler in the discharge line of the draft tube evacuation air compressor is supplied from the forebay with a connection on the suction of the fire and service pump.

Treated water system

All treated water for use at this project is supplied from the City of Kingsport Water Department. A complete piping system supplies the plumbing fixtures in the powerhouse and visitors' building. The air-conditioning unit in the control bay and two service outlets in the oil purification building are supplied from this system. Lawn sprinklers in the visitors' parking area and adjacent to the access road to the top of the dam are also supplied from this system.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 785-gallon concrete septic tank under the pavement, 23 feet west of the service bay. The effluent from the tank discharges into a perforated pipe laid in crushed rock under the riprap of the tailrace.

The waste from the toilet fixtures in the visitors' building at the north end of the dam discharges into a 2,000-gallon concrete septic tank approximately 25 feet west of the building. The effluent from the tank discharges into a subsurface tile field.

Drainage and unwatering

All powerhouse roof drainage is piped to the tailrace. All other drainage is piped to the station sump. The station sump is below the elevation 1207 floor of the service bay and is serviced by two 300-gallon-per-minute, turbine-type pumps discharging directly to the tailrace. The pumps are operated automatically by float switch controls.

An unwatering system for the draft tubes and scroll cases is used to permit inspection and repair of the underwater parts. Each

scroll case is equipped with a screened outlet and a 12-inch drain line with shutoff valve. When a unit intake gate is closed, the water in the scroll case drains to tailwater level through the wicket gates and through the opened valve in the 12-inch drain line into the draft tube. Each draft tube is equipped with a screened outlet 15 inches above the low point of the draft tube. A 12-inch drain pipe, with shutoff valve, connects each draft tube to the station drainage and unwatering sump.

Two 3,000-gallon-per-minute, turbine-type pumps are manually operated during unwatering periods and discharge directly into the tailrace. These pumps may be used to augment the station drainage pumping capacity.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is used for protection of the generators and the oil purification and storage room in the powerhouse. This system consists of three banks of 50-pound cylinders—an initial, delayed, and reserve bank of 10 cylinders each. The initial discharge bank is arranged for simultaneous discharge of 10 cylinders to either generator or to the oil purification and storage room. The reserve bank is arranged with interconnecting piping and controls to function in the same manner. The delayed discharge bank is arranged for intermittent release of cylinders to maintain a sufficient concentration in the generator housing to prevent rekindling. Discharge to either generator is initiated automatically by closing of a thermostat or by operation of the generator differential relays. Manual control is also provided by closing a break-glass-type switch on the governor cabinet. Discharge of carbon dioxide to the oil purification and storage room is initiated manually by control switch or automatically by thermostats.

There is a separate carbon dioxide system in the oil purification building in the switchyard. Manual closing of a switch or automatic closing of a thermostat will discharge four 50-pound cylinders into the purification room.

Portable carbon-dioxide fire extinguishers of various sizes are placed at convenient locations in the powerhouse. One 150-pound, dry powder, buggy-type fire extinguisher is stored in the oil purification building for use in the switchyard.

General fire protection for the powerhouse, switchyard, and transformer yard is supplied from the raw water fire and service system. Three fire hydrants are provided in the switchyard, and a fire hose cart, complete with wrenches, reel, two 50-foot lengths of fire hose, and two nozzles, is stored in the oil purification building. The electrical equipment in the transformer yard is protected by an automatic fixed sprinkler system, which is described in detail in chapter 13, "Fire Protection." Fire hose connections in the powerhouse and control bay are each equipped with a valve, 75 feet of unlined linen hose, hose rack, and a nozzle.

The 600-gallon-per-minute fire booster pump located in the oil purification building supplies adequate pressure to the system for use of fire-fighting equipment. The pump is operated by either of

three methods as follows: (1) starts automatically when transformer sprinkler system is turned on, (2) is started and stopped from a push-button station near the pump whenever fire hydrants in the switchyard are to be used, and (3) is started manually for powerhouse fire hose use from a test switch on the main control board.

Service equipment

The machine shop is equipped with the machines required for routine maintenance of the power plant equipment. The machine shop equipment, which is arranged along one wall of the rotor erection space in the powerhouse service bay, is listed in table 14, page 626.

Heating, ventilating, and air conditioning

Air conditioning is provided for the communications room for the protection of electrical equipment. The remainder of the powerhouse and the visitors' building are mechanically ventilated. Electric unit heaters located throughout the buildings supply heat to rooms or areas where occupancy may be expected and where freezing or excessive dampness may occur. Portable electric heaters supplement the permanently connected heaters.

The communications room air-conditioning unit is a self-contained packaged unit complete with refrigerant compressor, water-cooled condenser, fan, cooling coils, filters, and controlling devices.

The combined capacities of the heating, ventilating, and air-conditioning systems are as follows:

Cubic feet per minute of air supplied and exhausted	181,500
Kilowatts of installed electric heating	250.5
Horsepower of refrigeration	5

CHATUGE

The Chatuge Dam (fig. 141) is on the upper reaches of the Hiwassee River at river mile 121.0 in North Carolina. About one-half of the reservoir area extends into the State of Georgia. The project was initially constructed for storage with no generating equipment, thereby providing stream flow regulation and increasing the firm power of the downstream hydro plants. Construction of the dam and water discharge facilities was authorized as part of the World War II emergency program, as a means of supplying a substantial block of additional power in the system without the manufacture of additional generating equipment. The initial project included a rolled earth fill dam, flashboard-controlled spillway on the right river bank, an intake tower, 12-foot-diameter steel penstock extending in a concrete culvert through the dam, and a valve house with a 78-inch Howell Bunger valve for stream flow regulation.

Subsequently a generating station has been installed in place of the valve house. The project (fig. 142) now includes a powerhouse with a generating capacity of 10,000 kilowatts from a single unit. The reservoir provides a useful controlled storage capacity of 229,300

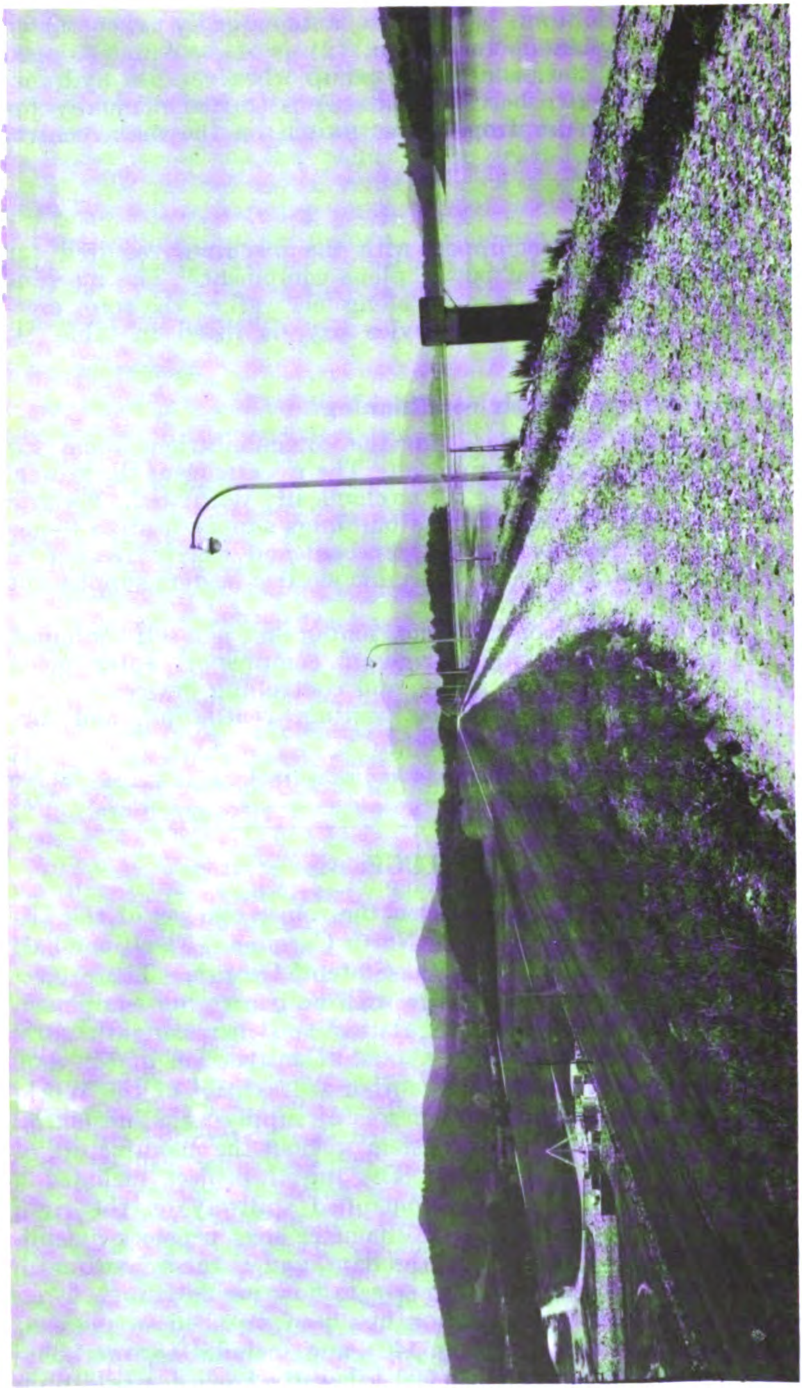


FIGURE 141.—*Chatuge Dam—powerhouse at left, intake tower at right.*

acre-feet. Authorization, construction, operation, and cost data are as follows:

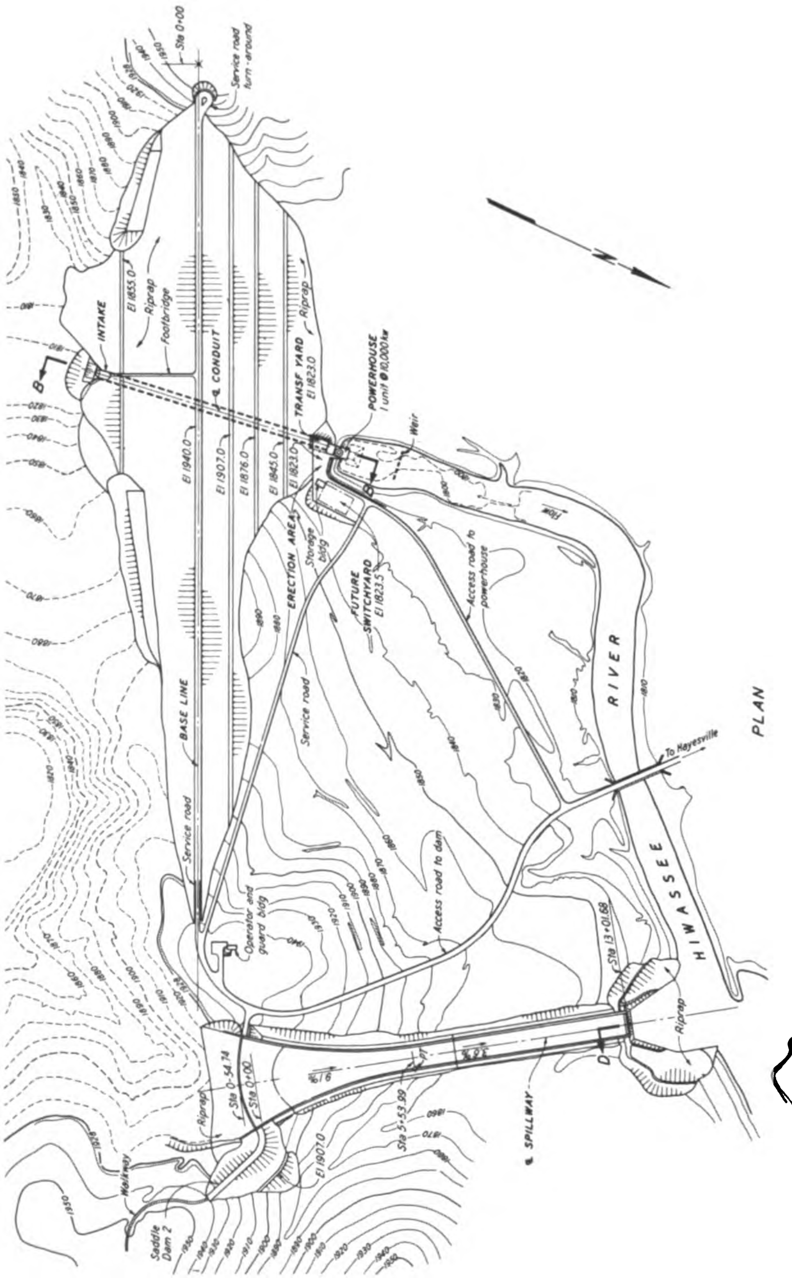
Authorizations:	
Project	July 17, 1941
Power unit	September 25, 1951
Construction started:	
Project	July 17, 1941
Power unit	August 14, 1952
Dam closure	February 12, 1942
First storage release	June 25, 1943
Commercial operation of unit	December 9, 1954
Cost of the single-unit project, including switchyard	$9,285,901

The Chatuge Dam, shown in figure 141, is an impervious rolled-earth-fill embankment with a crest length of 2,850 feet. The dam attains a maximum height of 144 feet above the foundation and a maximum width of 980 feet at the base. The spillway, at the right end of the main dam, has a 325-foot curved crest converging to an 80-foot chute section. Flashboards at the crest provide a maximum controlled water surface at elevation 1928. The spillway chute is 1,356 feet long and ends in a 5-foot high sill on a rock ledge at the river bank.

The intake tower (fig. 141) consists of a vertical shaft with a 25-foot inside diameter extending above maximum reservoir level. A trashrack is constructed over the waterway entrance. Two hydraulically operated slide gates are arranged side by side in the base of the tower to permit closure for inspection and maintenance of the penstock. A 15-ton service crane for handling the trashracks, the bulkheads, and the slide gates is installed in the crane house which tops the tower. A light footbridge connects the tower with the crest of the embankment. Heavy materials to be moved in or out of the tower are handled from a barge through a hatch opening in the floor of the overhanging portion of the crane house.

The conduit is a 12-foot diameter steel penstock, placed inside the diversion culvert through the embankment, which connects to the spiral steel scroll case of the generating unit in the powerhouse. The 78-inch Howell-Bunger valve was relocated with a connection on the downstream side of the scroll case to allow discharge of water without power generation or when the unit is operating as a synchronous condenser. Occasion for such use was so infrequent that appreciable investment for attachment of the valve to the spiral case did not appear justified. Because of the smallness of the spiral case and the powerhouse structure the valve was placed on the centerline of the case which is offset 9 feet from the centerline of the penstock inlet to the case. When the valve was operated for test purposes it began to show unusual discharge characteristics and after a few hours operation at 50 percent opening the valve body failed.

The primary cause of the failure was attributed to poor hydraulic entrance conditions caused by the offset between the centerline of the penstock and the centerline of the valve with resulting change in direction of water flow. Because of previous excellent operating experience with this valve in its original location on the end of the penstock it was concluded that had the spiral case installation been arranged for direct axial flow, no operating difficulty would have been experienced with the valve. Since relocation of the valve was impossible with the structure completed, the valve was removed


PLAN
HIWASSEE RIVER
INTAKE
℄ CONDUIT
BASE LINE
TRANSF YARD
El 1823.0
POWERHOUSE
1 unit @ 10,000 kw
Weir
Flow
ERECTION AREA
Storage bldg
FUTURE SWITCHYARD
El 1823.5
Access road to powerhouse
Service road
Access road to dam
Operator and guard bldg
Footbridge
Riprap
El 1855.0
El 1940.0
El 1907.0
El 1876.0
El 1845.0
Service road turn-around
Sta 0+00
Sta 0-54.74
Sta 5+53.99
Sta 13+01.68
℄ SPILLWAY
To Hayesville
Saddle Dam 2
Walkway
El 1907.0

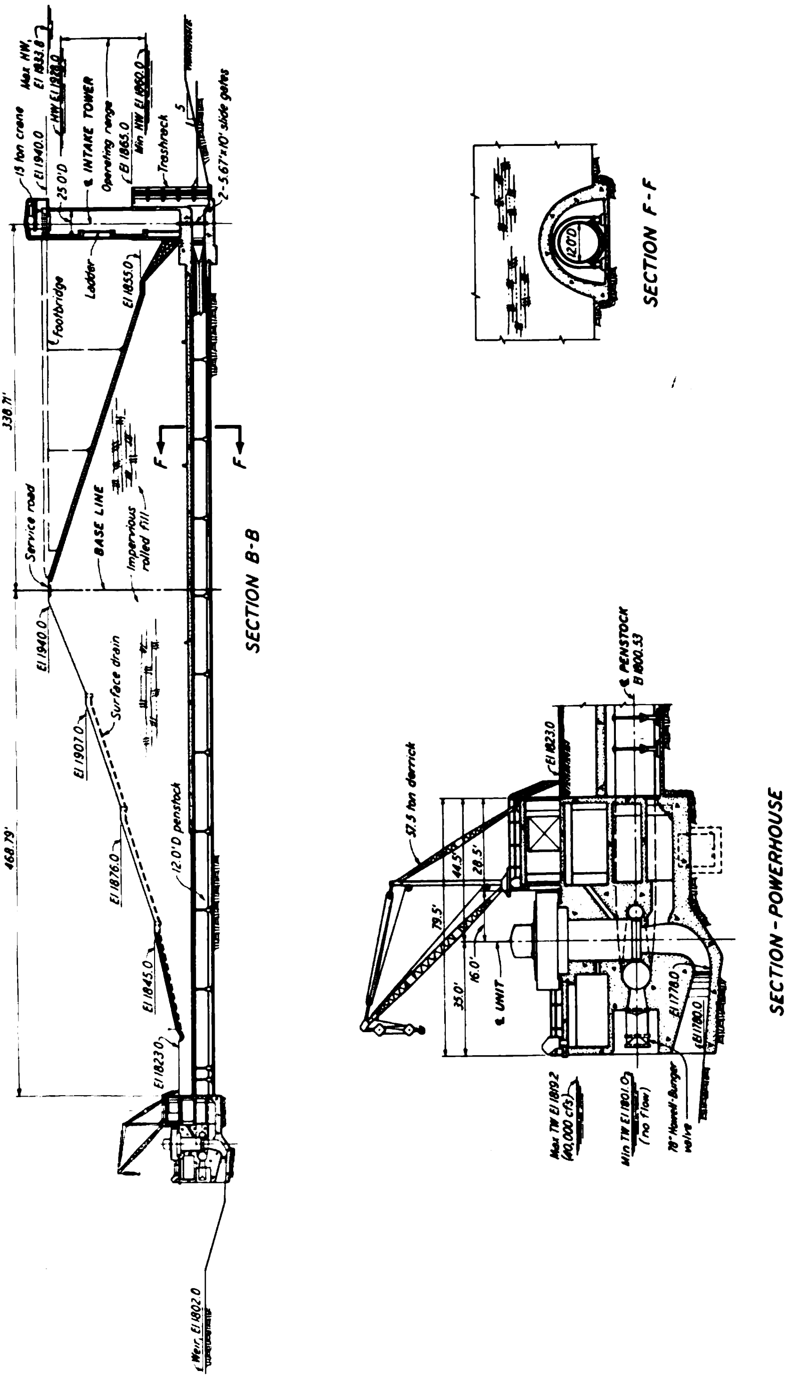


Figure 142.—*Chatuge—plan and sections.*

from the spiral case and the opening in the case was closed by welding in a section of steel plate.

The powerhouse, shown in figure 143, is an outdoor type of reinforced concrete construction, 36 feet long by 79.5 feet wide by 60 feet high. Electrical equipment rooms are upstream from the unit, and a room on the downstream side of the unit below the generator deck contains the Howell-Bunger valve drive and other mechanical equipment. A 57.5-ton derrick is installed on the powerhouse structure for erection and maintenance of the unit.

Turbine

The vertical Francis-type hydraulic turbine, manufactured by the James Leffel & Co., is direct-connected to the generator. The turbine is rated 13,800 horsepower at a net head of 100 feet and operates at a speed of 180 revolutions per minute. It is designed to operate satisfactorily under any head from a minimum of 53 feet to a maximum of 121 feet and is most efficient at a net head of about 108 feet. It is also designed to withstand a maximum runaway speed of 334 revolutions per minute. At rated conditions the value of specific speed is 67, and the centerline of the runner is set approximately 4 feet below normal tailwater elevation, giving a plant sigma of 0.35.

The Chatuge unit has a riveted plate-steel spiral case and cast-steel stay ring. The stay ring forms the main foundation ring of the turbine and the eight stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. The runner is an integral steel casting having 14 buckets, and the water to the runner is controlled by 16 wicket gates. The turbine shaft is guided by a grease-lubricated, babbit bearing located above the head cover. Grease is supplied to the bearing by the same automatic greasing equipment which is used to grease the wicket gate mechanism. From 0.5 to 1.0 cubic inch of grease is forced into the bearing at 15 minute intervals, and the bearing is arranged so that the waste grease drops into the draft tube and is discharged into the tailrace. A cooling jacket surrounds the bearing and is supplied with water from the station raw water system. The bearing is provided with the usual safety devices to shut down the unit and give alarm in case of high temperature, as well as an additional device for alarm and shutdown in case the bearing does not receive grease for any reason.

Construction specifications covering the field erection of this turbine are included in appendix A.

Governor

A single cabinet-actuator-type governor, manufactured by the Woodward Governor Co., is provided for this unit. The governor is complete with governor head, sump tank, pressure tank, oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the Hiwassee control room. There are two oil pumps of the herringbone-gear type, one of which supplies oil to the pressure tank while the other acts as a spare. Each pump has a capacity of 75 gallons per minute at a pressure of 300 pounds per square inch and is driven by a 20-horsepower motor. The sump tank is in the base of the

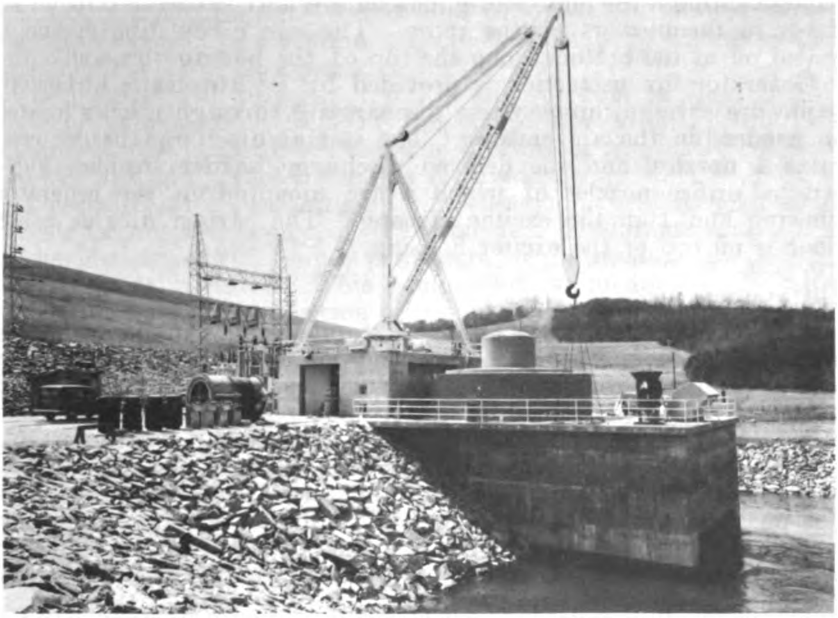


FIGURE 143.—*Chatuge powerhouse.*

actuator cabinet, and the pressure tank, which has a volume of 56 cubic feet, is inside the governor cabinet.

Generator

The generator, manufactured by the Westinghouse Electric Corp., has a normal rating of 11,111 kilovolt-amperes, or 10,000-kilowatts continuous output at 0.9 power factor, 6,900 volts, 3 phase, 60 cycles, and operates at 180 revolutions per minute. The generator is the vertical-shaft type, totally enclosed, and cooled by forced-air circulation through six water-cooled heat exchangers within the housing. The exciters are mounted on the upper bracket and are directly connected to the generator shaft.

Four combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the underside of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system. The brakes are applied by an automatic brake valve. Oil pressure at 2,000 pounds per square inch for jacking is applied by a portable hand-operated oil pump.

The combination Kingsbury-type thrust and segmental guide bearing is below the rotor and is designed for a maximum load of 122.5 tons. The bearing is immersed in oil which is cooled by water circulated through coils immersed in the oil reservoir. The bearing oil reservoir has a capacity of 625 gallons.

Circulation of cooling air through the generator is supplied by fans on the rotor, which force the hot air through the air coolers and over the top of the stator for recirculation. The air is cir-

culated through the main and pilot exciters and returned through air ducts to the blowers on the rotor. The air circulating system is sealed off at the bottom along the top of the bearing bracket.

Generator fire protection is provided by an automatic carbon dioxide fire extinguishing system discharging through nozzles located in headers in the air housing. The initial discharge header contains 4 nozzles, and the delayed discharge header supplies 5 restricted-orifice nozzles of which 4 are mounted in the generator housing and 1 in the exciter housing. The carbon dioxide relief door is on top of the exciter housing.

Oil systems

The governor and lubricating oil storage tank and pump are on the floor below the generator deck on the downstream side of the unit. The generator bearing oil reservoir and the governor oil sump are arranged to be drained by gravity to a portable oil storage tank when the oil requires purification. The 1,150-gallon-capacity portable tank and used oil are removed through a hatch in the deck by the powerhouse derrick for transportation to the Hiwassee powerhouse for purification. Upon return of the purified oil the 26-gallon-per-minute oil pump is used to fill the generator bearing oil reservoir and governor system. Separate drain and fill lines prevent return of contaminated oil to the system.

An insulating oil storage tank and pump are located in the transformer yard adjacent to the powerhouse. The tank, mounted on concrete saddles, has a capacity of 3,200 gallons and is used to store the oil when draining of the oil-insulated electrical equipment is required. The 55-gallon-per-minute outdoor-type insulating oil pump has separate suction and discharge connections to the tank. Valved connections for flexible hose attachment to both of these lines connect the pumping and storage facilities to the main transformer, to other electrical equipment, or to a portable purifier furnished by the Division of Power Operations.

The two slide gates, which serve as head gates in the intake tower, are raised and lowered by means of hydraulic cylinders located above the bonnet of each gate. Oil pressure for operation of the gates is normally supplied by a 20-gallon-per-minute pump with a discharge pressure of 1,200 pounds per square inch. Emergency closure of the head gates is made by remote and local control of an emergency oil pump having a capacity of 120 gallons per minute and a discharge pressure of 800 pounds per square inch. The emergency pump is automatically started to break the safety stud in each gate hanger and lower the gates by a contact of the float switch, indicating excessive leakage in the culvert. The emergency pump is stopped by limit switches on the operating rods when both gates are closed. The head gate oil pumps and a 330-gallon oil storage tank are on the elevation 1818.5 landing in the intake tower. A complete piping system conveys the oil to and from the cylinders.

Compressed air systems

A compressed air system, utilizing the 20.8-cubic-foot-per-minute, air-cooled, station and governor air compressor, is installed in the powerhouse for the generator brakes and service outlets. The com-

pressor, with an available discharge pressure of 300 pounds per square inch, is automatically controlled to supply the 100-pound-per-square-inch station air system. There is a complete piping system including a 50-cubic-foot air receiver.

The governor oil pressure tank, in the governor cabinet, is supplied by manual operation of the compressor at 300-pound-per-square-inch discharge pressure. The pressure is frequently checked, and the air supply replenished as required.

A portable, air-cooled, single-stage, electric-motor-driven air compressor having a capacity of 105 cubic feet per minute and a discharge pressure of 100 pounds per square inch is available for general service where required. This compressor is intended to be used during periods of construction or repair work when the demand for compressed air is greater than the capacity of the stationary air compressor. The portable compressor may be connected into the powerhouse air system through a service connection on the exterior wall near the powerhouse main entrance. The air compressor also serves the Nottely project. Specifications for this compressor are included in appendix B.

Figure 211, page 422, and figure 213, page 432 in chapter 7, "Compressed Air Systems," show the governor air compressor and the portable air compressor at this project.

A separate compressed air system for draft tube evacuation depresses the water level in the draft tube for operation of the unit as a synchronous condenser. Electrically controlled, air-operated valves controlled by switches on the governor cabinet and interlocked through gate position switches and the generator breaker automatically admit the air to the space under the head cover when the wicket gates are closed. When the water level is depressed below the bottom of the runner, operation of the air valves is controlled by float switches to maintain this level. One 200-cubic-foot air receiver and a stationary air compressor are located in the equipment room below the generator deck. The compressor is a stationary, 2-stage, air-cooled, angle compressor with a capacity of 115 cubic feet per minute and a discharge pressure of 100 pounds per square inch. The system includes control equipment for automatic operation of the compressor.

Raw water system

The raw water system provides water for unit cooling and lubrication, station service, and fire protection. Water flows by gravity from an intake in the scroll case through a strainer to the generator air coolers, to the generator bearing oil cooling coils, and to the turbine bearing cooler, packing box, and upper runner seal. The intake and strainer also supply the fire hose connections and raw water service outlets throughout the powerhouse.

A motor-operated gate valve serves as a complete shutoff for all water to the unit. The valve is automatically opened or closed when the unit is started or stopped by remote control from the Hiwassee control room. Flow through the generator air coolers is automatically controlled by a motor-operated thermostatically controlled proportioning valve actuated by a thermometer bulb in the generator housing.

The raw water supply lines to the unit are equipped with flowmeters to indicate low flow. The generator air cooler flowmeter contains one contact to sound a local alarm. Flowmeters in the turbine water supply line and the generator bearing cooling water supply line contain two low flow contacts, one to sound a local alarm and an alarm in the Hiwassee control room, and the other to shut down or prevent starting the unit.

Treated water system

A well downstream from the right embankment provides the treated water requirements of the station, consisting of drinking fountains and sanitary fixtures in the operator and guard building near the east end of the dam and in the powerhouse. A pumphouse mounted over the well contains the well pump which has a minimum capacity of 240 gallons per hour. A 220-gallon capacity storage tank in the operator and guard building provides a small amount of storage capacity and pressure requirements. The tank is equipped with a float switch controlling the operation of the well pump and the hypochlorinator. The only treatment necessary is the addition of the hypochlorite solution. Consideration is being given to abandonment of the operator and guards building, in which event the chlorinating equipment together with a small hydropneumatic storage tank will be located in the powerhouse.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 540-gallon septic tank in the switchyard at the southeast corner of the powerhouse. The effluent from the tank discharges into a subsurface tile field approximately 50 feet west of the powerhouse.

The waste from the toilet facilities in the operator and guard building discharges into a 485-gallon septic tank on the west side of the building. The effluent from the tank discharges into a ditch along the toe of the dam.

Drainage and unwatering

All powerhouse roof drainage is piped to the tailrace. All other drainage is piped to the station sump. Intake tower drainage and leakage from the steel penstock to the concrete conduit flows to the station sump through a 6-inch line equipped with a motor-operated gate valve. In case of excessive leakage from the penstock, the motor-operated gate valve is closed by a float switch, thereby preventing this drainage from overloading the station sump pumping capacity. The station sump is located in the substructure of the powerhouse. It is serviced by two 500-gallon-per-minute, turbine-type pumps discharging directly to the tailrace. The pumps are automatically controlled by a float switch in the sump.

An unwatering system for the draft tube and scroll case is used to permit inspection and repair of the underwater parts. The scroll case is equipped with a screened outlet and a 16-inch drain line with a shutoff valve. When the intake slide gates are closed the water in the penstock and scroll case drains through the wicket

gates and opened valve in the 16-inch drain line into the draft tube. A suitable air vent prevents collapse of the penstock. The draft tube is equipped with a screened outlet 15 inches above the low point of the draft tube. An 18-inch drain pipe connects the draft tube to the 24-inch unwatering pump well. A watertight joint is provided between the top of the well and the pump base, since the pump is located below maximum tailwater.

One 5,000-gallon-per-minute, vertical, turbine-type pump, mounted in the 24-inch pump well, is manually controlled to operate during unwatering periods and discharges directly into the tailrace at a point approximately 195 feet downstream from the end of the draft tube. This pump is shown in figure 248, page 522, of chapter 11, "Drainage Systems."

Fire protection

An automatic carbon-dioxide fire-extinguishing system is used for protection of the generator. The system consists of two banks of 50-pound cylinders mounted on a single stand. One bank of 8 cylinders provides the initial discharge and is arranged for simultaneous release of all 8 cylinders to the generator housing. The other bank, also of 8 cylinders, provides restricted discharge and is released through the restricted-orifice nozzles in the generator and exciter housings to maintain a sufficient concentration of carbon dioxide to prevent rekindling. Discharge to the generator is initiated automatically by closing of a thermostat or by operation of the generator differential relays. Manual control is also provided.

Eight 15-pound portable carbon-dioxide fire extinguishers are placed at convenient locations in the powerhouse and the operator and guard building. One wheeled-type, 100-pound carbon-dioxide fire extinguisher is used for protection of the transformer yard.

General fire protection for the powerhouse is supplied from the raw water fire and service system. Two fire hose connections in the powerhouse are each equipped with a 1½-inch valve, 75 feet of unlined linen hose on a semiautomatic rack, and an adjustable nozzle.

Service equipment

A 10-inch sensitive drill, a two-wheel 7-inch bench grinder, an anvil together with a workbench, and a few small tools are available in the powerhouse for minor service work. Major repairs to the powerhouse equipment requiring machine shop work are to be made at Hiwassee.

Heating and ventilating

The powerhouse, intake tower, and the operator and guard building are mechanically ventilated principally for the removal of heat from electrical equipment or solar radiation and for the relief of dampness. Electric unit heaters supplemented by portable electric units are located throughout the buildings. A total of 17,400 cubic feet per minute of air is supplied and exhausted by the ventilating systems and 85 kilowatts of electric heating is provided at this project.

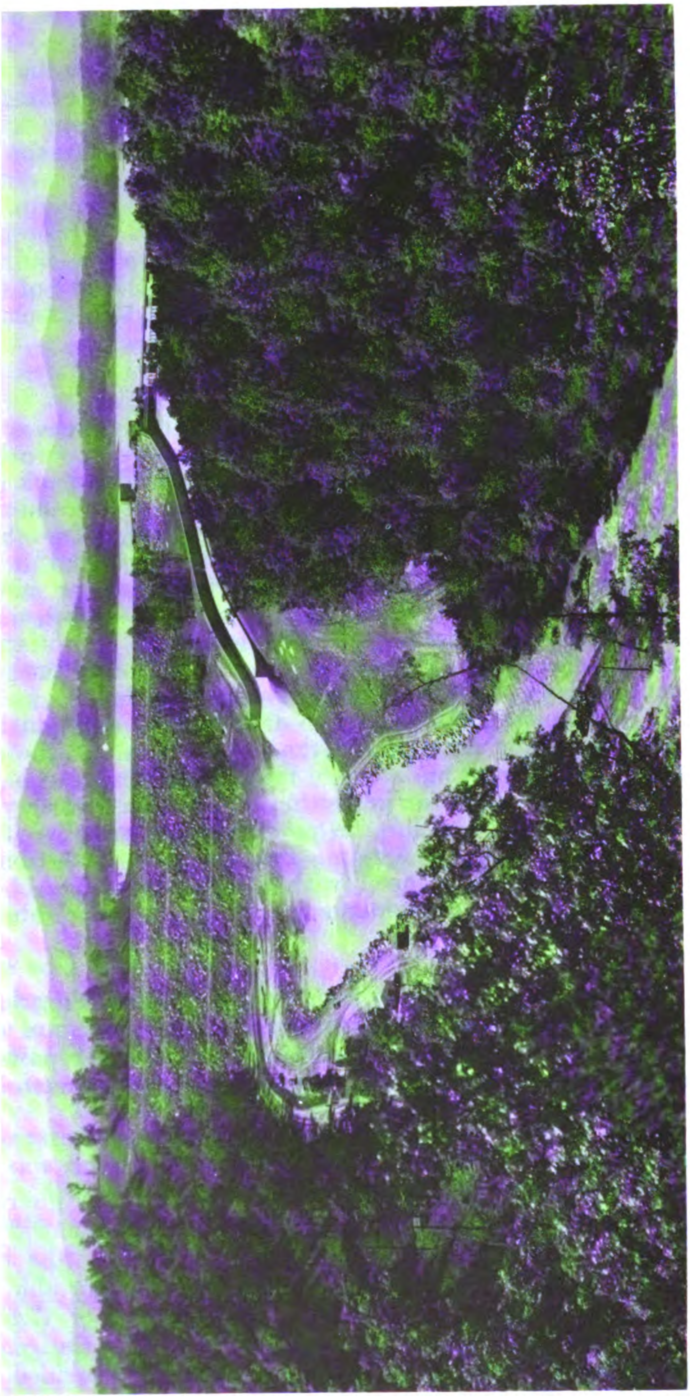


FIGURE 144.—*Nottely Dam before addition of powerhouse.*

NOTTELY

The Nottely Dam is on the Nottely River about 21 miles above its confluence with the Hiwassee River. Construction of Nottely and Chatuge projects, which are similar in many respects, was planned to run concurrently as part of the World War II emergency program. To expedite design, manufacture of equipment, and construction work, as many features of the projects were duplicated as possible. Both projects were initially constructed as storage projects to supplement the dependable power production of downstream hydro plants.

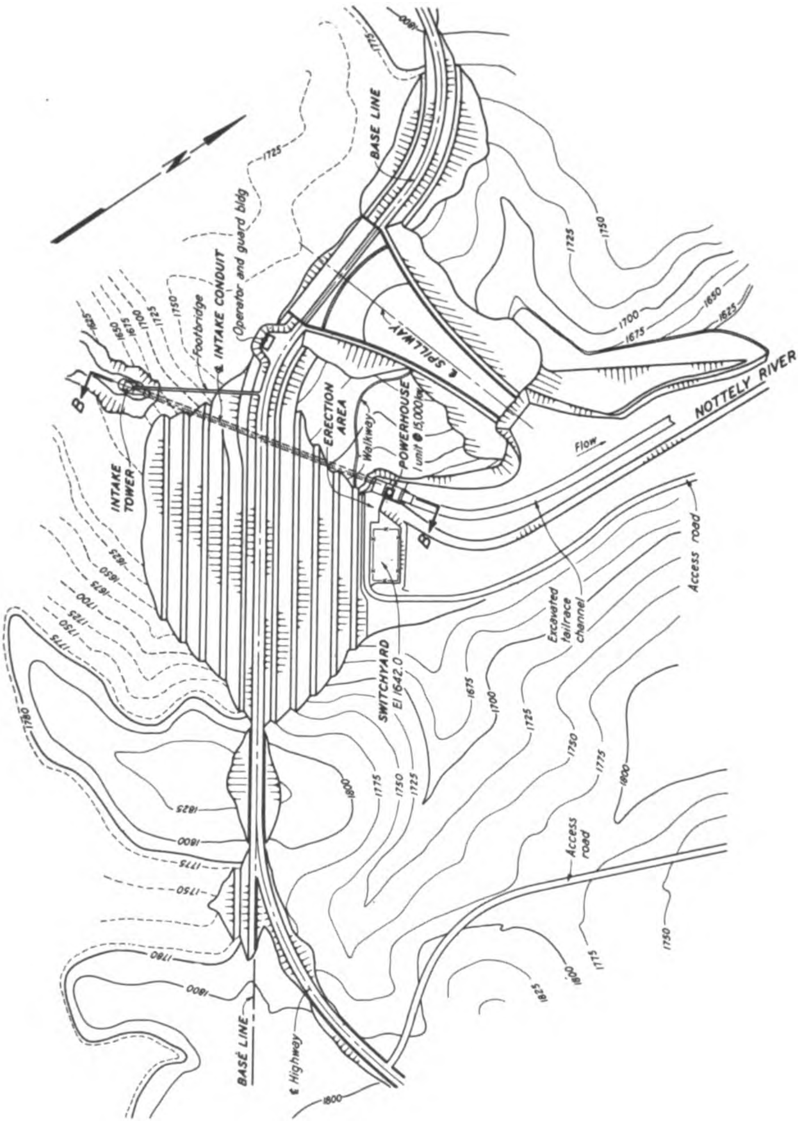
As completed in 1942 (fig. 144), the Nottely project consisted of a combined earth- and rock-fill dam, an overflow chute spillway, a reinforced concrete dry tower intake, a discharge tunnel through the left abutment, a valve house containing a 78-inch Howell-Bunger valve, and an operator and guard building atop the dam.

Construction of a generating station to replace the valve house was completed in January 1956. The completed project includes a powerhouse with a single generator having a capacity of 15,000 kilowatts, an excavated tailrace, and a switchyard. The plan and sections of the project are shown in figure 145, the new powerhouse nearly completed is shown in figure 146, and the Howell-Bunger valve discharging from the valve house replaced by the powerhouse is shown in figure 147. The reservoir provides a useful controlled storage capacity of 171,200 acre-feet. Authorization, construction, operation and cost data are as follows:

Authorizations:	
Project	July 17, 1941
Power unit	September 25, 1951
Construction started:	
Project	July 17, 1941
Power unit	December 3, 1952
Dam closure	January 24, 1942
First storage release	October 1, 1942
Commercial operation of unit	January 10, 1956
Cost of the single-unit project, including switchyard	$8,039,132

The Nottely Dam is an embankment with a crest length (including the spillway) of 2,300 feet. The dam attains a maximum height of 184 feet and a maximum width of 720 feet at the base. The spillway, at the left end of the main dam, has a 300-foot curved crest at elevation 1775, which converges to an 80-foot chute section. Flashboards provide a maximum controlled pool level at elevation 1780. The spillway chute is 621 feet long and ends in a ski-jump sill at the river bank. A view of the spillway discharging is shown in figure 144.

The intake tower is essentially the same as the tower at Chatuge except for height, consisting of a vertical shaft with a 25-foot inside diameter, with a trashrack constructed over the waterway entrance. Two hydraulically operated slide gates are arranged side by side in the base of the tower for closure of the conduit. The diversion tunnel through the left abutment is lined and serves as a conduit for the power unit. A 15-ton service crane for handling the trashracks, the bulkheads, and the slide gates is installed in the crane house on top of the tower. A light footbridge connects the tower with the crest of the embankment. Heavy materials to be moved


N
BASE LINE
℄ INTAKE CONDUIT
Operator and guard bldg
Footbridge
℄ SPILLWAY
ERECTION AREA
Walkway
POWERHOUSE
1 unit @ 15,000kw
INTAKE TOWER
NOTTELY RIVER
Flow
SWITCHYARD
El 1642.0
Excavated tailrace channel
Access road
Access road
BASE LINE
℄ Highway
B
B
1625
1650
1675
1700
1725
1750
1775
1780
1800
1825

PLAN

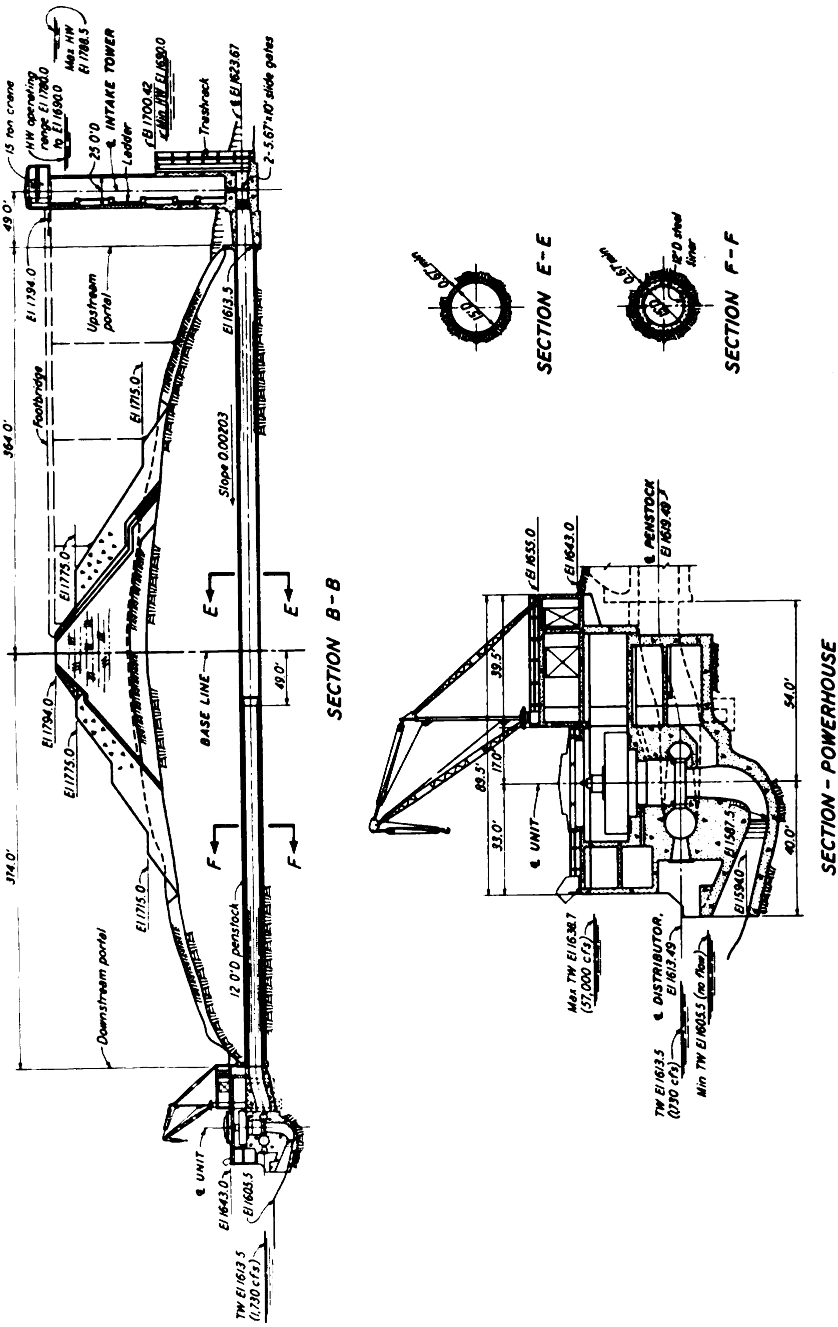


FIGURE 145.—*Nottely—plan and sections.*

FIGURE 146.—*Nottely powerhouse.*

in or out of the tower are handled from a barge through a hatch opening in the floor of the overhanging portion of the crane house.

The powerhouse (shown with construction nearly completed in figure 146) is the semioutdoor type of reinforced concrete construction. Provision was originally made for release of water downstream by the installation of a Howell-Bunger valve with a connection on the downstream side of the spiral steel scroll case. The operation of a similar arrangement at Chatuge proved to be unsatisfactory, however, and the opening for the valve was closed by welding a steel plate to the scroll case lining.

The unit block of the powerhouse is 41 feet wide. The powerhouse is 96.5 feet long and about 70 feet high. The four-story equipment bay is upstream from the unit. A 70-ton stiffleg derrick mounted on the powerhouse roof is used for erection and maintenance of the unit and for handling equipment and materials in the erection area. Overhanging the Howell-Bunger valve space on the downstream side of the unit are two floors containing additional equipment and storage space. Hatches through the deck and the elevation 1632 floor permit equipment to be lowered to both levels.

A 26-foot-square hatch is provided over the unit in the powerhouse roof deck for erection and maintenance of the unit. There is also a 3.5-foot-square hatch over the draft tube unwatering pump for erection and maintenance of the pump.

There is an outdoor erection area on a reinforced concrete slab at the right side of the powerhouse. The switchyard is separated from the downstream toe of the dam by the access road. The fenced-in area of the present and future switchyard is 156 feet long by 80 feet wide, parallel to the base line of the dam.

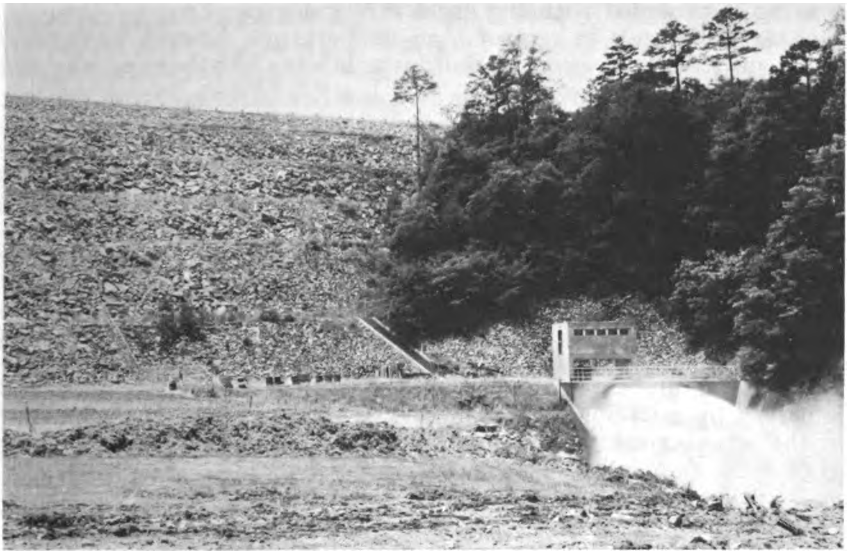


FIGURE 147.—*Nottely—78-inch Howell-Bunger valve discharging from valve house which was later replaced by powerhouse installation.*

The gross head on the turbine was increased by about 5 feet by excavation of the tailrace channel for a distance of about 970 feet.

Turbine

The single vertical Francis type hydraulic turbine manufactured by the James Leffel & Co. is direct connected to the generator. The turbine is rated at 21,000 horsepower at a net head of 124 feet and operates at a speed of 180 revolutions per minute. It is designed to operate satisfactorily under any head from a minimum of 76 feet to a maximum of 166 feet and is most efficient at a net head of about 138 feet. It is also designed to withstand a maximum runaway speed of 334 revolutions per minute. At rated conditions the value of specific speed is 63, and the centerline of the runner is set about 0.5 feet below normal tailwater elevation, giving a plant sigma of 0.27.

The Nottely unit has a riveted plate-steel spiral case and cast-steel stay ring. The stay ring forms the main foundation ring of the turbine, and the eight stay vanes act as vertical columns to transmit to the foundation the weight of the structure and equipment above. The runner is an integral steel casting having 14 buckets, and the water to the runner is controlled by 16 cast steel wicket gates. The turbine shaft is guided by a grease-lubricated, babbitt-lined bearing located above the head cover. Grease is supplied to the bearing by the same automatic greasing equipment which is used to grease the wicket gate mechanism. From 0.5 to 1.0 cubic inch of grease is forced into the bearing at 15-minute intervals, and the bearing is arranged so that the waste grease drops into the draft tube and is discharged into the tailrace. A cooling jacket surrounds the bearing and is supplied with cooling water from the station raw water system. The

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bearing is provided with the usual safety devices to give alarm and shut down the unit in case of high temperature, as well as an additional device for alarm and shutdown in case the bearing does not receive grease for any reason.

Governor

A single cabinet-actuator-type governor manufactured by the Woodward Governor Co. is provided for the Nottely unit. The governor is complete with governor head, sump tank, pressure tank, oil pumps, permanent magnet generator for driving the governor head, and the necessary auxiliaries for remote control of the unit from the Hiwassee powerhouse. Two oil pumps of the herringbone-gear type are provided, one of which supplies oil to the pressure tank while the other acts as a spare. Each pump has a capacity of 75 gallons per minute at a pressure of 300 pounds per square inch and is driven by a 20-horsepower motor. The sump tank is in the base of the actuator cabinet; and the pressure tank, which has a volume of 56 cubic feet, is inside the governor cabinet.

Generator

The generator, manufactured by the Westinghouse Electric Corp., has a normal rating of 16,667 kilovolt-amperes or 15,000 kilowatts continuous output at 0.9 power factor, 13,800 volts, 3 phase, 60 cycles, and operates at 180 revolutions per minute. The generator is the vertical-shaft type, totally enclosed, and cooled by forced-air circulation through six water-cooled heat exchangers within the housing. The exciters are mounted on the upper bracket and are directly connected to the generator shaft.

Four combination brakes and jacks are mounted on the lower bearing bracket and bear against a brake ring on the under side of the rotor rim. Compressed air at 100 pounds per square inch is supplied for braking by the station compressed air system. The brakes are applied by an automatic brake valve. Oil pressure at 1,900 pounds per square inch for jacking is applied by a portable hand-operated oil pump.

The combination Kingsbury type thrust and segmental guide bearing is located below the rotor and is designed for a maximum load of 180 tons. The bearing is immersed in oil which is cooled by water circulated through coils immersed in the oil reservoir. The bearing oil reservoir has a capacity of 650 gallons.

Circulation of cooling air through the generator is supplied by fans on the rotor, which force the hot air through the air coolers and over the top of the stator for recirculation. The air circulating system is sealed off at the bottom along the top of the bearing bracket, and at the top below the main exciter.

Generator fire protection is provided by an automatic carbon dioxide fire extinguishing system discharging through nozzles located in headers in the air housing. The initial discharge header contains eight nozzles, and the delayed discharge header contains twelve restricted-orifice nozzles.

Oil systems

The governor and lubricating oil storage tank and transfer pump are in the mechanical equipment room at elevation 1622. The 28-

gallon-per-minute lubricating oil pump is used to drain the generator bearing oil reservoir and the governor oil sump to a portable oil storage tank when the oil requires purification. The 1,150-gallon-capacity portable tank and used oil are removed through hatches in the floor and deck above by the powerhouse derrick for transportation to the Hiwassee powerhouse for purification. Upon return of the purified oil the transfer pump is used with an alternate arrangement of the suction and discharge hose connections to fill the generator bearing oil reservoir and governor system. Separate drain and fill lines prevent return of contaminated oil to the system.

An insulating oil storage tank and pump are located in the switchyard. The tank, mounted on concrete saddles, has a capacity of 4,280 gallons and provides storage when required to drain the main transformer. The 59-gallon-per-minute outdoor-type insulating oil pump has separate suction and discharge connections to the tank. Valved connections for flexible hose attachment to both of these lines connect the pumping and storage facilities to the main transformer or to a portable purifier furnished by the TVA's Division of Power Operations.

The two slide gates, which serve as head gates in the intake tower, are raised and lowered by means of hydraulic cylinders above the bonnet of each gate. Oil pressure for operation of the gates is normally supplied by a 20-gallon-per-minute pump with a discharge pressure of 1,200 pounds per square inch. Emergency closure of the head gates is provided by remote and local control of an emergency oil pump having a capacity of 120 gallons per minute and a discharge pressure of 1,000 pounds per square inch. The emergency pump is stopped automatically by limit switches on the operating rods when both gates are closed. The head gates oil pumps and a 330-gallon oil storage tank are located on the elevation 1639 landing in the intake tower. A complete piping system conveys the oil to and from the cylinders.

Compressed air systems

A compressed air system, utilizing the 20.8-cubic-foot-per-minute, air-cooled, station and governor air compressor, is installed in the powerhouse for the generator brakes and service outlets. The compressor, with an available discharge pressure of 300 pounds per square inch, is automatically controlled to supply the 100-pound-per-square-inch station air system. A complete piping system is provided, including a 50-cubic-foot air receiver.

The governor oil pressure tank, in the governor cabinet, is supplied by manual operation of the compressor at 300-pound-per-square-inch discharge pressure. The pressure is frequently checked, and the air supply replenished as required.

One portable air compressor was purchased for use at Nottely and Chatuge projects when required for general service. The preceding section on Chatuge compressed air systems (page 286) describes this compressor and its uses.

Raw water system

The raw water system provides water for unit cooling and lubrication, station service, and fire protection. Water flows by gravity

from an intake in the scroll case through a strainer to the generator air coolers, to the generator bearing oil cooling coils, and to the turbine bearing cooler, packing box, and upper runner seal. The intake and strainer also supply the fire hose connections and raw water service outlets throughout the powerhouse.

A motor-operated gate valve serves as a complete shutoff for all water to the unit. The valve is automatically opened or closed when the unit is started or stopped by remote control from the Hiwassee control room. Flow through the generator air coolers is automatically controlled by a motor-operated, thermostatically controlled proportioning valve actuated by a thermometer bulb in the generator housing.

The raw water supply lines to the unit are equipped with flowmeters to indicate low flow. The generator air cooler flowmeter contains one contact to sound a local alarm. Flowmeters in the turbine water supply line and the generator bearing cooling water supply line contain two low flow contacts, one to sound a local alarm and an alarm in the Hiwassee control room, and the other to shut down or prevent starting the unit.

Treated water system

A well, between the spillway and the powerhouse on the left bank, provides the treated water requirements of the station, consisting of drinking fountains and sanitary fixtures in the operator and guard building on top of the dam and in the powerhouse. A pumphouse mounted over the well contains the well pump which has a capacity of 192 gallons per hour. An air chamber is installed on the pump discharge to iron out surges in the system.

A 220-gallon-capacity storage tank in the operator and guard building provides a small amount of storage capacity and pressure requirements. The tank is equipped with a float switch controlling the operation of the well pump and the hypochlorinator. The only treatment necessary is the addition of the hypochlorite solution. As at the Chatuge project plans are under consideration for the abandonment of the operator and guard building at the dam, in which case the chlorinating facilities will be relocated in the powerhouse and a hydropneumatic storage tank will be installed.

Sewage disposal

The waste from the toilet facilities in the powerhouse discharges into a 540-gallon concrete septic tank located adjacent to the north side of the building. The effluent discharges into the subsurface tile field with an underdrain terminating in coarse stone under the riprap of the tailrace.

The waste from the toilet facilities in the operator and guard building discharges into a 485-gallon septic tank located on the west side of the building. The effluent from the tank discharges into the Nottely Reservoir.

Drainage and unwatering

All powerhouse roof drainage and intake tower drainage is piped to the tailrace. All other powerhouse drainage is piped to the station

sump, which is in the substructure of the powerhouse. It is serviced by two 20-gallon-per-minute, duplex sump pumps discharging directly to the tailrace. The pumps are float-switch controlled.

An unwatering system for the draft tube and scroll case is used to permit inspection and repair of the underwater parts. The scroll case and penstock are equipped with screened outlets and 6-inch drain lines connecting to the draft tube. These drain lines are equipped with shutoff valves. When the intake slide gates are closed the water in the penstock and scroll case drains through both the wicket gates and the opened valves in the 6-inch drain lines into the draft tube. A suitable air vent is provided on the downstream side of the intake slide gates. The draft tube is equipped with a screened outlet 9 inches above the low point of the draft tube. An 18-inch drain pipe connects the draft tube to the 24-inch unwatering pump well.

One 1,070-gallon-per-minute, turbine-type pump operates during unwatering periods and discharges directly into the tailrace at a point approximately 50 feet downstream from the end of the draft tube.

Fire protection

An automatic carbon-dioxide fire-extinguishing system is used for protection of the generator. The system consists of two banks of 50-pound cylinders mounted on a single stand. One bank of 8 cylinders, provides the initial discharge and is arranged for simultaneous release of all 8 cylinders to the generator housing. The other bank, also of 8 cylinders, supplies the delayed discharge and is released through the restricted-orifice nozzles in the generator air housing to maintain a sufficient concentration of carbon dioxide to prevent rekindling. Discharge to the generator is initiated automatically by closing of a thermostat or by operation of the generator differential relays. Manual control is also provided.

Ten 15-pound portable carbon-dioxide fire extinguishers are placed at convenient locations in the powerhouse and the operator and guard building. One 150-pound, dry powder chemical, wheeled-type fire extinguisher is stored in the powerhouse for use in the switchyard.

General fire protection for the powerhouse is supplied from the raw water fire and service system. Three fire hose connections in the powerhouse are each equipped with a 1½-inch valve, 75 feet of unlined linen hose on a semiautomatic hose rack, and an adjustable nozzle.

Service equipment

Small service tools similar to those described for Chatuge were provided at Nottely, with the anticipation that any major repair work would be done at the Hiwassee machine shop.

Heating and ventilating

Ventilating and heating equipment similar to that described for the Chatuge project was installed at Nottely. A total of 41,100 cubic feet of air per minute is supplied and exhausted by the ventilating system and 122 kilowatts of electric heating is installed.

OTHER PLANTS

The six other acquired hydro plants mentioned at the start of this chapter were acquired by TVA from private interests and are now operated and maintained by TVA. Major improvements have been made at some of these projects for economy and safety of operation, although no additional power installations were undertaken. These projects are briefly discussed in the following paragraphs for the purpose of presenting a complete description of all the hydro plants operated by TVA.

Blue Ridge

The Blue Ridge project was acquired from the Tennessee Electric Power Co. August 16, 1939, at a cost of $5,040,042. Commerical operation of the station began in July 1931. This diversion type project is on the Toccoa River on the upper watershed of the Ocoee River. The dam is a semihydraulic earth-fill type with a gate-controlled saddle spillway. A multipurpose project, the reservoir provides a useful controlled storage volume of 186,300 acre-feet, and the single-unit power station has a generating capacity of 20,000 kilowatts. The vertical Francis turbine, manufactured by the S. Morgan Smith Co., has a rated capacity of 30,000 horsepower at a net head of 147 feet. The open, air-cooled, vertical-shaft generator, manufactured by the Westinghouse Electric Corp., has a normal rating of 25,000 kilovolt-amperes or 20,000 kilowatts at 0.8 power factor. No significant additions or alterations have been made by TVA at this project. Figure 148 shows a general view of the powerhouse, switchyard, and surge tank.

Columbia

The Columbia project was acquired from the Tennessee Electric Power Co. August 16, 1939, at a cost of $197,000. The original cost (not TVA's purchase price) was $324,000. This minor tributary project is on the Duck River which empties into Kentucky Reservoir. The station contains two units with a total generating capacity of

FIGURE 148.—*Blue Ridge Dam, surge tank, and powerhouse.*

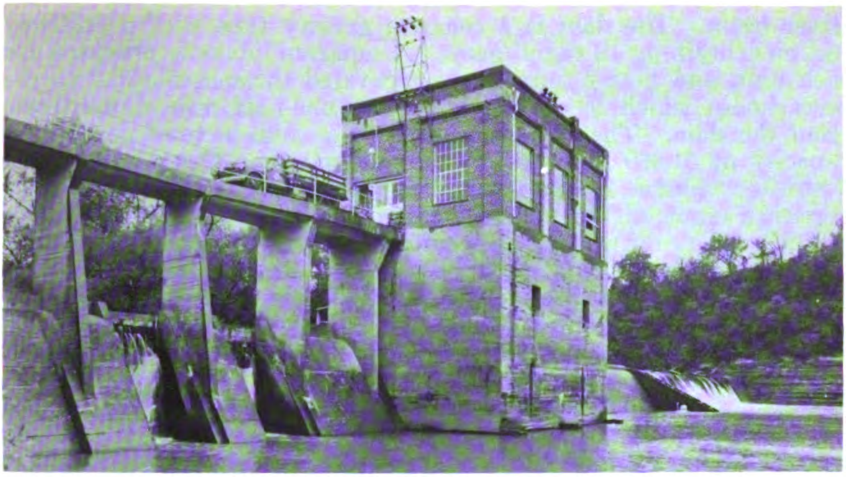

FIGURE 149.—*Columbia Dam and powerhouse.*

800 kilowatts and includes a switchyard. A view of the powerhouse and dam is shown in figure 149.

Great Falls

The Great Falls project was acquired from the Tennessee Electric Power Co. August 16, 1939, at a cost of $3,518,603. Commercial operation of unit 1 began in 1916 and of unit 2 in 1925. This diversion-type project is on the Caney Fork River immediately downstream from the mouth of the Collins River, in the Cumberland

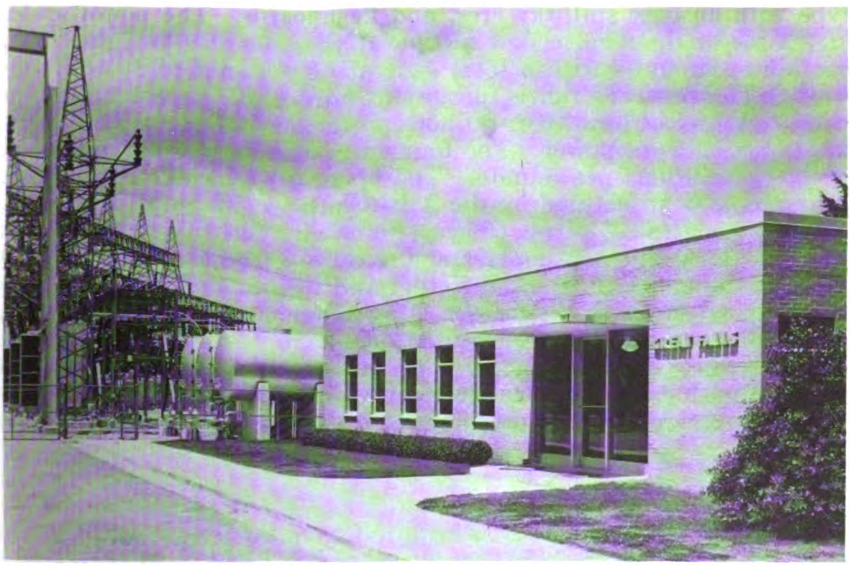

FIGURE 150.—*Great Falls hydro plant—new switchyard and control building.*

River basin. The dam is a concrete gravity type with a spillway section containing 18 radial gates. A separate intake is provided for each unit, and power tunnels are excavated through the hill to the powerhouse which is on the left bank one-half mile downstream from the dam. The two-unit powerhouse adds a total generating capacity of 31,860 kilowatts to the system. The reservoir contains a storage volume for low-water releases of 49,400 acre-feet. The vertical Francis turbines, manufactured by the Allis-Chalmers Manufacturing Co., have rated capacities of 12,000 horsepower at a net head of 105 feet and of 22,200 horsepower at a net head of 142 feet for units 1 and 2, respectively. The open, air-cooled, vertical-shaft generators have normal ratings of 16,000 kilovolt-amperes or 15,360 kilowatts at 0.96 power factor and of 20,625 kilovolt-amperes or 16,500 kilowatts at 0.8 power factor for units 1 and 2, respectively. Leakage under the right abutment and through the peninsula formed by the Collins River was largely corrected by extensive grouting work done by TVA in 1946. Improvements to the power facilities included conversion of the units for remote control from a new control building on top of the hill above the powerhouse and a new switchyard adjacent to the control building. The project, upon completion of the improvements, represented a total investment of $6,403,315 by TVA. A view of the new control building and switchyard is shown in figure 150.

Nolichucky

The Nolichucky project was acquired from the East Tennessee Light & Power Co. June 29, 1945, at a cost of $1,472,812. Commercial operation of the first 2 units began in 1913 and of the remaining 2 units in 1923. This project is on the Nolichucky River in the French Broad River basin. The dam is a concrete gravity overflow type with an ogee spillway crest and flashboards. The powerhouse, at the toe of the nonoverflow section of the dam on the right bank, contains four units with a total generating capacity of 10,640 kilowatts. The vertical Francis turbines of units 1 to 3 have a maximum output at 70-foot head of 4,000 horsepower, and of unit 4 at 70-foot head of 5,200 horsepower. The four units operate at a normal speed of 164 revolutions per minute. The open, air-cooled, vertical-shaft generators, manufactured by the Allis-Chalmers Manufacturing Co., are each 2,500-volt, 3-phase, 60-cycle units with the following ratings: unit 1— 2,500 kilovolt-amperes at 0.8 power factor; unit 2— 3,800 kilovolt-amperes at 0.8 power factor; and units 3 and 4—3,500 kilovolt-amperes at 0.8 power factor. A switchyard is on the right bank. No significant additions or alterations have been made by TVA at this project. Plans are presently underway for the installation of certain shutdown protective devices for the turbines and generators. A view of the powerhouse and dam is shown in figure 151.

Ocoee No. 1

The Ocoee No. 1 project was acquired from the Tennessee Electric Power Co. August 16, 1939, at a cost of $2,680,000. Commercial operation of the first four units began in 1912, and unit 5 was added in 1914. Substantial reconstruction work on the units was

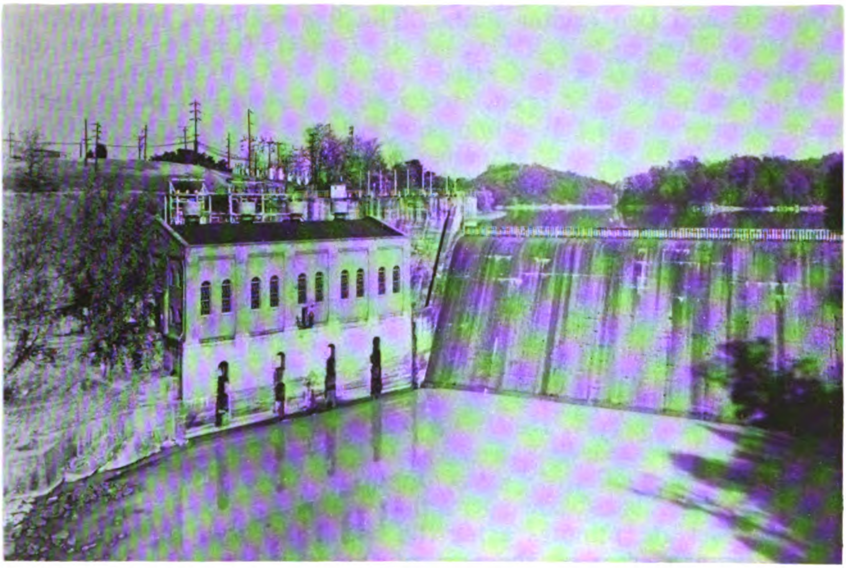

FIGURE 151.—*Nolichucky powerhouse and dam.*

carried out during the period from 1930 to 1937. This tributary-type project is on the Ocoee River at river mile 11.9, in the Hiwassee River basin. The dam is a concrete gravity type with an arched spillway section. Wooden flashboards on the spillway section are 70 inches high and designed to wash out when submerged 2 feet. The powerhouse, on the right bank downstream from the nonoverflow section, contains five generating units with a total capacity of 18,000

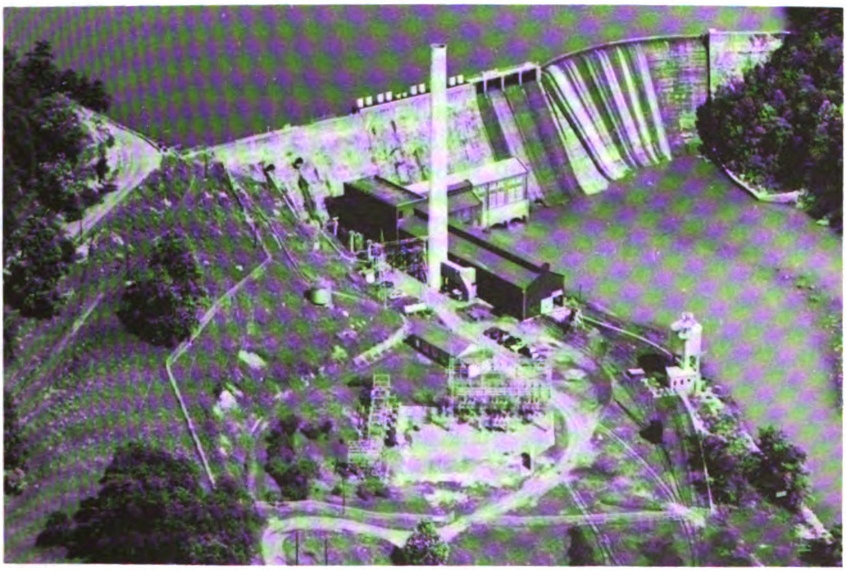

FIGURE 152.—*Ocoee No. 1 Dam and hydro plant with steam plant at left of tailrace.*

kilowatts and two exciter units. The five turbines, manufactured by the S. Morgan Smith Co., are horizontal Francis, twin-runner, double-wicket units with a rated capacity of 7,400 horsepower each at 110-foot head. The open, air-cooled, horizontal-shaft generators, manufactured by the Westinghouse Electric Corp., have a normal rating of 4,500 kilovolt-amperes or 3,600 kilowatts at 0.8 power factor, 2,300 volts, 3 phase, 60 cycles, and operate at 360 revolutions per minute. Subsequent improvements made by TVA at this station include extension of the switchyard and the addition of a transformer fire protection system of the water-fog type, which is described in detail in chapter 13, "Fire Protection." A view of the reservoir, dam, and powerhouse is shown in figure 152.

Ocoee No. 2

The Ocoee No. 2 project was acquired from the Tennessee Electric Power Co. August 16, 1939, at a cost of $2,595,264. The two units were initially installed in October 1913. Considerable reconstruction work has been performed, most important of which was the repair of unit 2 generator following its failure in April 1949. This failure followed several minutes after the accidental tripping off of full load. Human error on the part of the operator, under emergency conditions, was the principal cause of the ultimate runaway speed and disintegration of the generator. Design of the unit, which had operated many years, was in no way to blame.

This diversion type project is on the Ocoee River. The dam, at river mile 24.2, is a rock-filled timber crib type constructed of 10- by 10-inch timbers. It has a length of 450 feet and maximum height of 30 feet. An open, rectangular flume with a Tainter-gate-controlled intake connects the dam and forebay, at which point there is an automatic 8-syphon spillway. An extension flume from the forebay to the penstock intake contains three 4.75- by 9.75-foot water passages, two of which are in use with provision for a third penstock. An 8-foot, motor-operated, butterfly type valve is provided at the entrance of the two 8-foot-diameter penstocks leading to the powerhouse which is located at river mile 19.9 on the left bank. The two-unit powerhouse adds a total generating capacity of 21,000 kilowatts to the system. The small, badly silted pond at the dam has no useful storage capacity, and the dam is used for diversion purposes only. The turbines, manufactured by the I. P. Morris Co. and Wellman Seaver Morgan, are horizontal Francis, double-runner type with ratings at 250-foot head at 15,000 horsepower for units 1 and 2, respectively. The generators are open, air-cooled, horizontal-shaft type, each with a normal rating of 13,125 kilovolt-amperes or 10,500 kilowatts, 0.8 power factor, 6600 volts, 3 phase, 60 cycles, and operate at a normal speed of 360 revolutions per minute. Unit 1, rewound in May 1953, was manufactured by the General Electric Co., and unit 2, replaced in service in January 1951, by the Elliott Co. In addition to the repair of unit 2 generator, major improvements and additions made by TVA at this project include installation of a water-treatment plant and control equipment for remote control of the generating unit installed at Ocoee No. 3 hydro plant. Figure 153 shows a view of the replaced generator.

Studies and cost estimates have been prepared covering several additional improvements including relocation of the battery room,

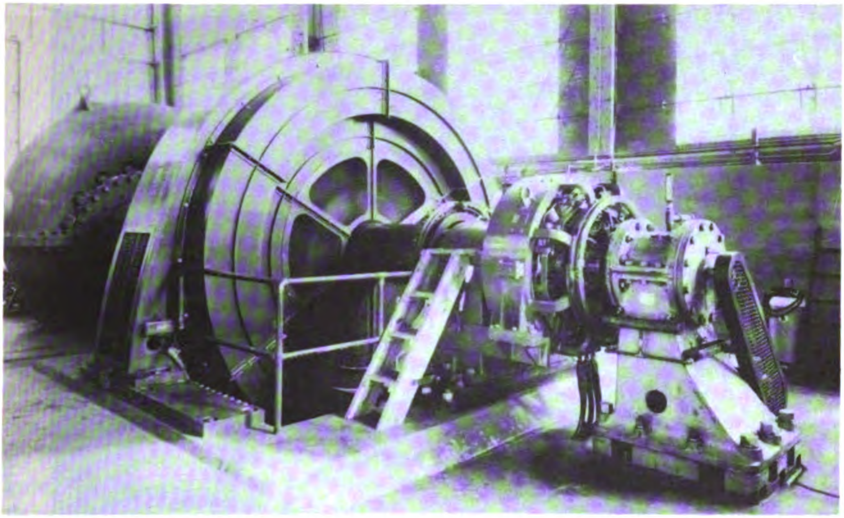

FIGURE 153.—*Repaired generator for Ocoee No. 2 project.*

enclosing and air conditioning of the switchboard operator's area, and the addition of toilet and locker facilities.

Retired stations

Nine minor hydro stations—Cadiz, Estill Springs, Harms, Lillards Mill, McMinnville, Sevierville, Shelbyville, Sparta, and Walter Hill—containing 14 small generating units totaling 3,281 kilowatts of capacity were acquired by TVA and subsequently retired from service.

ALCOA projects

Data concerning the principal features of the six major projects—Calderwood, Cheoah, Chilhowee, Nantahala, Santeetlah, and Thorpe—owned by the Aluminum Co. of America (ALCOA) are listed in table 1, page 4. In addition ALCOA owns nine smaller plants—Bear Creek, Bryson, Cedar Cliff, Dillsboro, Franklin, Mission, Queens Creek, Tennessee Creek, and Tuckasegee. The 15 ALCOA projects are all in the Tennessee Valley and contain 29 generating units with a total capacity of 425,960 kilowatts.

Cumberland plants (U.S. Army—Corps of Engineers)

The five plants—Center Hill, Cheatham, Dale Hollow, Old Hickory, and Wolf Creek—in the Cumberland Valley owned by the Corps of Engineers contain 16 units totaling 559,000 kilowatts of capacity in operation and 3 units totaling 36,000 kilowatts scheduled for operation in 1959. No additional data on these Cumberland plants are included in this report.

ADDITIONAL DATA—TVA HYDRO PROJECTS

Table 1 on page 4 lists additional information concerning the principal features of the water control projects in the Tennessee River Basin and the Great Falls project in the Cumberland Basin.

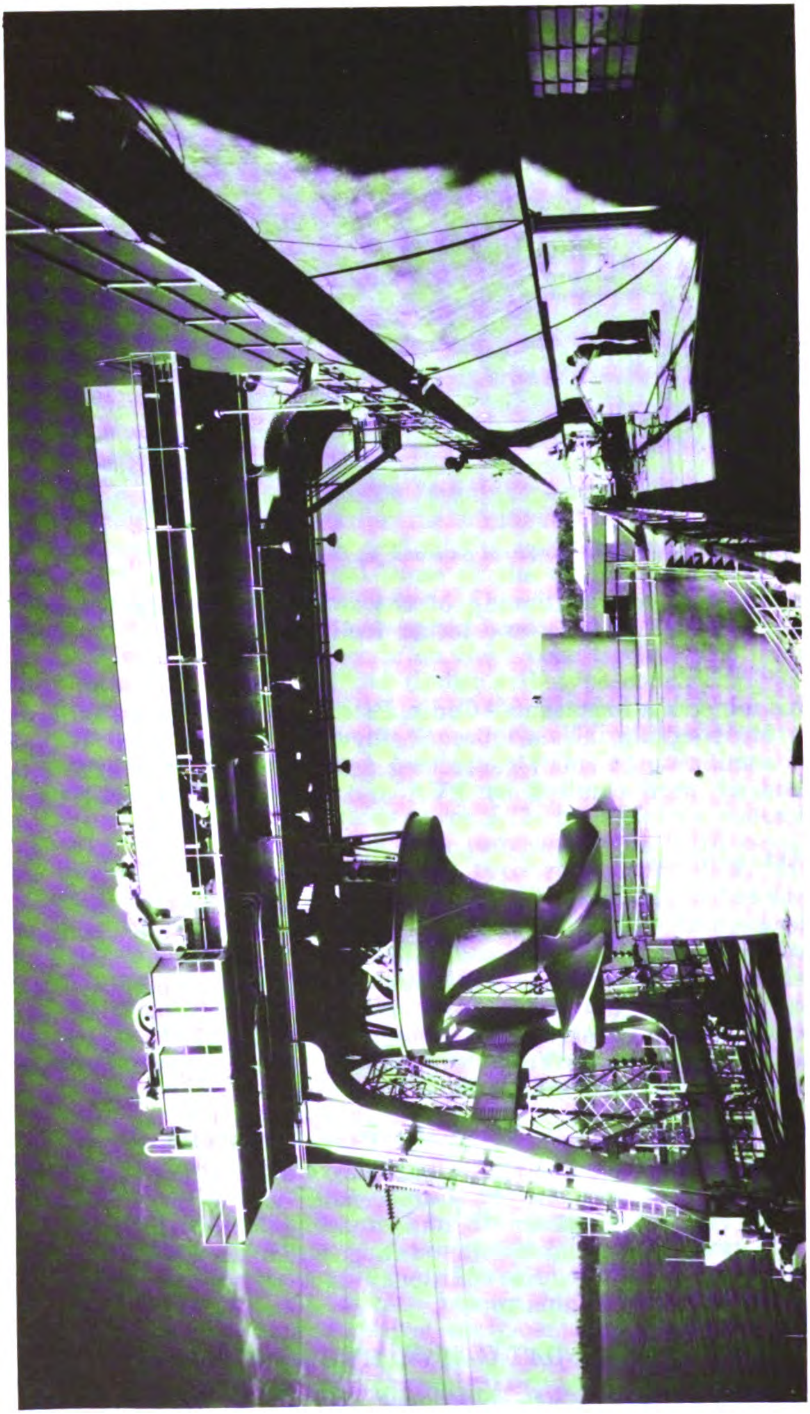

FIGURE 154.—*Fixed-propeller turbine runner—Wheeler.*

Chapter 3

HYDRAULIC TURBINES

This chapter discusses the factors concerning the design, selection, erection, and testing of hydraulic turbines in TVA plants, with a section at the end devoted to turbine inlet valves in penstocks.

The generating units installed in the 20 TVA-built projects, and in the 3 acquired where TVA installed additional units, have reaction turbines of both mixed and axial flow types because of the varying conditions of head, load, capacity, etc. With the exception of Wilson Dam, which has Francis turbines, the main-river developments have propeller turbines to meet more efficiently the varying conditions of head and load. These propeller turbines are the Kaplan type except at Wheeler where they are the fixed-propeller type (fig. 154). Storage developments on the five principal tributaries have moderate-head Francis turbine installations, while the so called secondary storage developments, on streams having relatively limited storage but steep slopes, are the tunnel and surge-tank type equipped with medium-head Francis machines. Figures 47 and 56, pages 84 and 99, are sections through powerhouses showing a typical Francis runner and a typical Kaplan runner, respectively. Table 3 lists the physical features and other data on the turbines which have been installed by TVA.

FACTORS AFFECTING SELECTION AND DESIGN

The economics of power-plant design is controlled among other things by the specific speed and critical sigma, i.e., the cavitation characteristics of the turbine selected. These factors are interrelated and, in a properly selected turbine, they are compatible. A higher specific speed results in lower-cost turbines, generators, and powerhouse, yet this higher speed must not be obtained at the expense of a safe plant sigma value, nor at the expense of energy lost in the draft tube because of the excessive discharge velocity. A margin of safety of a few feet over the limiting value of the static draft head should always be observed in order to keep the plant sigma above the critical sigma.

Furthermore, the turbine should be selected on the basis of its performance under the known operating conditions of the plant, i.e., variations in headwater and tailwater elevations, plant usage factor, and the relation between the power output at the particular plant to the power requirements of the integrated system. These basic rules were observed in selecting the turbines for TVA.

TABLE 3.—*Physical features of hydroelectric turbines installed by TVA*

Project→	Kentucky	Pickwick	Wilson (new)	Wheeler	Guntersville
Units installed	5	6	10	8	4
Ultimate plant installation	5	6	10	8	4
Type of turbine	Kaplan	Kaplan	V. Francis	F. Prop.	Kaplan
Rated horsepower	44,000	48,000	35,000	45,000	34,000
Maximum guaranteed horsepower	50,000	55,000	37,300	50,000	39,000
Rated head, feet (net)	48	43	92	48	36
Head for best efficiency, feet (net)	51	50–56	92	48	37
Maximum head, feet (net)	58.5	60	97.5	54	42
Minimum head, feet (net)	6	30	68	44	18
Rated speed, revolutions per minute	78.3	81.8	100	85.7	69.2
Maximum runaway speed, revolutions per minute	220	208	193	160	189
Specific speed at rating	130	163	66	144	145
Value of sigma at rating	0.96	0.98	0.30	0.78	1.05
Diameter of runner, inches, intake	260	292	129.625	264	265
Diameter of runner, inches, discharge	----------	----------	169	----------	----------
Distance centerline to bottom of runner, inches	----------	----------	67.5	----------	----------
Distance centerline to top of runner, inches	----------	----------	29	----------	----------
Number of blades or buckets	6	6 and 5	15	6	5
Number of guide vanes	24	24	20	24	20
Height of guide vanes, inches	100	112	58	112	107.875
Guide vane circle, diameter, inches	302	338	184	312	318.375
Rated discharge, cubic feet per second	9,000	11,200	4,000	9,200	9,800
Peripheral speed, turbine, normal feet per minute (discharge)	5,330	6,260	4,430	5,920	4,810
Peripheral speed, turbine, runaway feet per minute (discharge)	14,975	15,900	8,540	11,060	13,100
Elevation centerline distributor, feet	300	358.58	419.34	508.3	558
Elevation centerline runner, feet	291.90	349.50	419.34	499.04	549.87
Normal headwater elevation, feet	356	412	505	55	594
Normal tailwater elevation, feet	305	359	412	505	555

Unit spacing center to center, feet	77.5	80	55.5	76	78
Weight of rotating parts, turbine, tons	170	185	65	117	230
WR^2 of turbine, pound-foot^2 (million)	3.15	8.0	2.57	4.5	6.2
Shaft diameter, inches (nominal)	34	36	27.250	33.750	35
Shaft length, feet	16.75	18.02	25.79	23.89	23.25
Shaft guide bearing diameter, inches	38	40	30.750	37.500	37
Guide bearing lubrication	Water	Water	Water	Water	Water
Guide bearing material	Insurok	Insurok-Wood	Insurok	Rubber-Insurok	Insurok
Scroll case	Concrete	Concrete	Concrete	Concrete	Concrete
Gate servomotors:					
Volume, cubic inches	18,600	31,000	8,400	24,000	14,700
Operating time to open gates, seconds	8	6	7	8	8
Operating time to close gates, seconds	8	11	8	10	10
Hydraulic thrust at maximum head and rated speed, pounds	1,150,000	1,570,000	175,000	1,025,000	886,000
Weight and hydraulic thrust, pounds	1,490,000	1,940,000	304,000	1,260,000	1,346,000
Blade servomotors:					
Volume, cubic inches	30,000	37,300			22,560
Operating time to open blades, seconds	12	13			40
Operating time to close blades, seconds	14	12			40
Type of draft tube	Elbow	Elbow	Moody Cone	Elbow	Elbow
Turbine manufacturer	A.C.	A.C.	A.C.	B.S.	S.M.S.
Governor manufacturer	A.C.	A.C.	A.C.	Woodward	Woodward
Generator manufacturer	G.E.	W.	A.C.	G.E.	G.E.
WR^2 of generator, pound-foot^2 (million)	72.0	72.5	35.6	61.3	86.0
Elevation bottom draft tube, feet	243.0	294.0	381.09	450.0	497.0
Distance centerline unit to end of draft tube, feet	85.0	85.0	46.5	85.0	85.0
Pit diameter (lower)	29′ 6″	33′ 1″	18′ 8″	30′ 4″	30′ 0″

TABLE 3.—*Physical features of hydroelectric turbines installed by TVA*—Continued

Project→	Hales Bar (new)	Chickamauga	Watts Bar	Fort Loudoun	Norris
Units installed	2	4	5	4	2
Ultimate plant installation	2	4	5	4	2
Type of turbine	Kaplan	Kaplan	Kaplan	Kaplan	V. Francis
Rated horsepower	34,000	36,000	42,000	44,000	66,000
Maximum guaranteed horsepower	38,000	42,000	48,000	48,000	
Rated head, feet (net)	36	36	52	65	165
Head for best efficiency, feet (net)	41	48	57	70	180
Maximum head, feet (net)	40	52	60	70	195
Minimum head, feet (net)	15	20	40	40	135
Rated speed, revolutions per minute	69.2	75	94.7	105.8	112.5
Maximum runaway speed, revolutions per minute	189	231	243	282	220
Specific speed at rating	145	161	139	120	49
Value of sigma at rating	1.09	1.21	0.89	0.69	0.16
Diameter of runner, inches, intake	265	264	234	222	161
Diameter of runner, inches, discharge					165.187
Distance centerline to bottom of runner, inches					55.375
Distance centerline to top of runner, inches					21
Number of blades or buckets	5	5	5	5	19
Number of guide vanes	20	24	24	24	24
Height of guide vanes, inches	107.813	112	99.500	84.750	41.875
Guide vane circle, diameter, inches	318.375	312	276.500	276.500	189
Rated discharge, cubic feet per second	9,800	10,700	8,000	6,700	4,300
Peripheral speed, turbine, normal feet per minute (discharge)	4,800	5,180	5,810	6,150	4,860
Peripheral speed, turbine, runaway feet per minute (discharge)	13,110	15,970	14,900	16,400	9,520
Elevation centerline distributor, feet	599.0	632	676	735	832
Elevation centerline runner, feet	590.875	623.04	668.06	727.87	832
Normal headwater elevation, feet	633	682	740	812	1,006
Normal tailwater elevation, feet	597	632	682	742	826

Unit spacing center to center, feet	78	80	73	70	60
Weight of rotating parts, turbine, tons	212	210	141	145	82
WR^2 of turbine, pound-foot^2 (million)	6.2	6.7	3.61	3.61	2.6
Shaft diameter, inches (nominal)	35	33.500	32	32	35
Shaft length, feet	19.75	23.0	25.02	19.71	14.0
Shaft guide bearing diameter, inches	37	37	35.500	35.500	36
Guide bearing lubrication	Water	Water	Water	Water	Oil
Guide bearing material	Insurok	Insurok	Insurok	Insurok	Babbit
Scroll case	Concrete	Concrete	Concrete	Concrete	Pl. St. R.
Gate servomotors:					
Volume, cubic inches	14,700	20,680	18,000	19,900	16,900
Operating time to open gates, seconds	8	8	9	8.25	8
Operating time to close gates, seconds	8	10	9	8.75	9
Hydraulic thrust at maximum head and rated speed, pounds	892,000	1,052,000	952,000	1,036,000	500,000
Weight and hydraulic thrust, pounds	1,316,000	1,472,000	1,234,000	1,326,000	665,000
Blade servomotors:					
Volume, cubic inches	24,400	25,400	23,600	26,100	
Operating time to open blades, seconds	8	40	20	11.25	
Operating time to close blades, seconds	13	40	18	15.0	
Type of draft tube	Elbow	Elbow	Elbow	Elbow	Elbow
Turbine manufacturer	S.M.S.	B.S.	B.S.	B.S.	N.N.
Governor manufacturer	Woodward	Woodward	Woodward	Woodward	Woodward
Generator manufacturer	G.E.	A.C.	W.	A.C.	W.
WR^2 of generator, pound-foot^2 (million)	75.0	75.6	45.0	40.1	62.74
Elevation bottom draft tube, feet	538.0	572.0	622.0	684.0	795.0
Distance centerline unit to end of draft tube, feet	99.34	92.0	78.0	73.0	57.0
Pit diameter (lower)	30′ 0″	30′ 4″	27′ 0″	27′ 0″	19′ 6″

TABLE 3.—*Physical features of hydroelectric turbines installed by TVA*—Continued

Project→	Cherokee	Douglas units 1 & 2	Douglas units 3 & 4	Hiwassee unit 1	Hiwassee unit 2
Units installed	4	2	2	1	1 (pump-turbine)
Ultimate plant installation	4	2	2	1	1
Type of turbine	V. Francis	V. Francis	V. Francis	V. Francis	V. Francis
Rated horsepower	41,500	41,500	35,500	80,000	83,000
Maximum guaranteed horsepower	50,000	50,000	35,500	120,000	112,000 at 220′
Rated head, feet (net)	100	100	80	190	190
Head for best efficiency, feet (net)	110	110	88	200	240
Maximum head, feet (net)	146	130	130	245	254.5
Minimum head, feet (net)	55	62	47	142	135
Rated speed, revolutions per minute	94.7	94.7	90	120	105.9
Maximum runaway speed, revolutions per minute	189	179	191.5	235	161
Specific speed at rating	61	61	70.9	48	42.1
Value of sigma at rating	0.27	0.29	0.418	0.141	0.20
Diameter of runner, inches, intake	165	165	149	161	266
Diameter of runner, inches, discharge	177	177	180	165.187	182
Distance centerline to bottom of runner, inches	61	61	73	55.375	69
Distance centerline to top of runner, inches	28.437	28.437	33	21	23
Number of blades or buckets	15	15	15	19	6
Number of guide vanes	20	20	20	24	20
Height of guide vanes, inches	55.750	55.750	53.2187	41.875	46
Guide vane circle, diameter, inches	202	202	205.5	189	312
Rated discharge, cubic feet per second	4,400	4,400	3,750	4,300	3,900 (pump)
Peripheral speed, turbine, normal feet per minute (discharge)	4,390	4,390	4,240	5,200	7,370
Peripheral speed, turbine, runaway feet per minute (discharge)	8,300	8,300	9,030	10,180	11,200
Elevation centerline distributor, feet	930	876	876	1,277	1,271.00
Elevation centerline runner, feet	930	876	876	1,277	1,271.00
Normal headwater elevation, feet	1,035	978	1,000	1,472	1,524.5
Normal tailwater elevation, feet	925	873	872	1,273	1,276

Unit spacing center to center, feet	61	61	61	62.08	62.08
Weight of rotating parts, turbine, tons	88	88	84	71	210
WR^2 of turbine, pound-foot^2 (million)	3.2	3.2	2.5	2.6	18.0
Shaft diameter, inches (nominal)	33	33	31	36	40
Shaft length, feet	12.57	12.57	12.01	12.29	15.75
Shaft guide bearing diameter, inches	33.500	33.500	33.5	37	43
Guide bearing lubrication	Oil	Oil	Oil	Oil	Oil
Guide bearing material	Babbit	Babbit	Babbit	Babbit	Babbit
Scroll case	Pl. St. R.	Pl. St. R.	Pl. St. R.	Pl. St. R.	Pl. St. W.
Gate servomotors:					
Volume, cubic inches	12,850	12,850	14,500	16,500	22,575
Operating time to open gates, seconds	9	7.5	6.0	8	......
Operating time to close gates, seconds	9	10.0	7.5	10	......
Hydraulic thrust at maximum head and rated speed, pounds	210,000	210,000	360,000	410,000	306,000
Weight and hydraulic thrust, pounds	385,000	385,000	528,000	552,000	726,000
Blade servomotors:					
Volume, cubic inches	......	......	......	......	......
Operating time to open blades, seconds	......	......	......	......	......
Operating time to close blades, seconds	......	......	......	......	......
Type of draft tube	Elbow	Elbow	Elbow	Elbow	Elbow
Turbine manufacturer	S.M.S.	S.M.S.	S.M.S.	N.N.	A.C.
Governor manufacturer	Woodward	Woodward	Woodward	Woodward	Woodward
Generator manufacturer	G.E.	G.E.	G.E.	W.	A.C.
WR^2 of generator, pounds-foot^2 (million)	45.0	45.0	44.0	60.3	82.8
Elevation bottom draft tube, feet	893.0	839.0	839.0	1,240.0	1,238.50
Distance centerline unit to end of draft tube, feet	59.0	59.0	59.0	57.0	57.0
Pit diameter (lower)	19′ 0″	19′ 0″	19′ 11″	19′ 6″	30′ 0″

TABLE 3.—*Physical features of hydroelectric turbines installed by TVA*—Continued

Project→	Ocoee No. 3	Apalachia	Fontana	Watauga	South Holston
Units installed	1	2	3	2	1
Ultimate plant installation	1	2	3	2	1
Type of turbine	V. Francis	V. Francis	V. Francis	V. Francis	V. Francis
Rated horsepower	33, 500	53, 000	91, 500	34, 500	48, 500
Maximum guaranteed horsepower	33, 500	62, 000	91, 500	42, 000	56, 000
Rated head, feet (net)	280	360	330	216	180
Head for best efficiency, feet (net)	280	390	355	275	205
Maximum head, feet (net)	297	420	420	309	252
Minimum head, feet (net)	250	330	235	165	126
Rated speed, revolutions per minute	200	225	150	200	144
Maximum runaway speed, revolutions per minute	370	440	300	395	267
Specific speed at rating	32	33	32	45	48
Value of sigma at rating	0. 089	0. 073	0. 078	0. 135	0. 163
Diameter of runner, inches, intake	111	118	158. 125	108	142
Diameter of runner, inches, discharge	96. 750	103	144. 500	105. 5	141
Distance centerline to bottom of runner, inches	26. 750	36. 125	47. 750	32	36. 875
Distance centerline to top of runner, inches	7. 907	9. 625	14. 500	16. 250	14. 938
Number of blades or buckets	16	15	15	19	17
Number of guide vanes	18	20	20	18	20
Height of guide vanes, inches	15. 812	19. 250	29	24. 375	29. 745
Guide vane circle, diameter, inches	134. 500	138. 5	192	134	173
Rated discharge, cubic feet per second	1, 200	1, 500	2, 880	1, 725	2, 580
Peripheral speed, turbine, normal feet per minute (discharge)	5, 060	6, 075	5, 685	5, 920	5, 880
Peripheral speed, turbine, runaway feet per minute (discharge)	9, 375	11, 890	11, 350	11, 700	10, 900
Elevation centerline distributor, feet	1, 126	846	1, 285	1, 654	1, 495
Elevation centerline runner, feet	1, 126	846	1, 285	1, 654	1, 495
Normal headwater elevation, feet	1, 425	1, 267	1, 640	1, 925	1, 695
Normal tailwater elevation, feet	1, 119	840	1, 279	1, 650	1, 489

Unit spacing center to center, feet		44	56	40	
Weight of rotating parts, turbine, tons	27	32	73	22	48
WR^2 of turbine, pounds-foot^2 (million)	0.3	0.5	2.72	0.43	1.0
Shaft diameter, inches (nominal)	23	25	34	24	29
Shaft length, feet	9.66	8.37	16.67	7.92	10.44
Shaft guide bearing diameter, inches	23.500	25.500	34.250	25	33.5
Guide bearing lubrication	Oil	Oil	Oil	Oil	Oil
Guide bearing material	Babbit	Babbit	Babbit	Babbit	Babbit
Soroll case	Pl. St. R.	C. St.	Pl. St. W.	Pl. St. W.	Pl. St. R.
Gate servomotors:					
Volume, cubic inches	6,270	7,860	12,000	5,240	9,850
Operating time to open gates, seconds	10	6	6	6	6
Operating time to close gates, seconds	18	6.5	7	6	6
Hydraulic thrust at maximum head and rated speed, pounds	126,000	175,000	414,000	206,500	295,500
Weight and hydraulic thrust, pounds	180,000	240,000	559,000	248,000	392,090
Blade servomotors:					
Volume, cubic inches					
Operating time to open blades, seconds					
Operating time to close blades, seconds					
Type of draft tube	Elbow	Elbow	Elbow	Elbow	Elbow
Turbine manufacturer	S.M.S.	B.S.	A.C.	N.N.	S.M.S.
Governor manufacturer	Woodward	Woodward	A.C.	Woodward	Woodward
Generator manufacturer	W.	W.	W.	W.	W.
WR^2 of generator, pounds-foot^2 (million)	10.0	13.2	53.0	10.0	22.5
Elevation bottom draft tube, feet	1,101.0	821.58	1,250.0	1,631.42	1,465.17
Distance centerline unit to end of draft tube, feet	30.0	36.5	50.0	47.6	64.3
Pit diameter (lower)	14′ 0″	15′ 0″	19′ 0″	14′ 0″	16′ 9″

TABLE 3.—*Physical features of hydroelectric turbines installed by TVA*—Continued

Project→	Wilbur (new)	Boone	Fort Henry	Chatuge	Nottely
Units installed	1	3	2	1	1
Ultimate plant installation	1	3	2	1	1
Type of turbine	F. Prop	V. Francis	Kaplan	V. Francis	V. Francis
Rated horsepower	9,700	34,500	25,000	13,800	21,000
Maximum guaranteed horsepower	11,450	54,000	28,000	18,200	31,000
Rated head, feet (net)	58	90	61	100	124
Head for best efficiency, feet (net)	62	110	67	108	138
Maximum head, feet (net)	69	123	75	121	166
Minimum head, feet (net)	58	65	58	53	76
Rated speed, revolutions per minute	180	100	138.5	180	180
Maximum runaway speed, revolutions per minute	467	189	319	334	334
Specific speed at rating	111	67.1	129	67	63.2
Value of sigma at rating	0.51	0.35	0.65	0.35	0.27
Diameter of runner, inches, intake	115	143	159	81	90.0
Diameter of runner, inches, discharge	----------	174	----------	94.375	101.0
Distance centerline to bottom of runner, inches	----------	67	----------	40.25	43.875
Distance centerline to top of runner, inches	----------	33.75	----------	16	17.66
Number of blades or buckets	6	16	6	14	14
Number of guide vanes	20	24	24	16	16
Height of guide vanes, inches	46.765	59.335	61.086	32.25	35.31
Guide vane circle, diameter, inches	132.625	190	189	117.25	128.375
Rated discharge, cubic feet per second	1,750	3,660	4,060	1,430	1,760
Peripheral speed, turbine, normal feet per minute (discharge)	5,420	4,560	5,760	4,440	4,760
Peripheral speed, turbine, runaway feet per minute (discharge)	14,050	8,610	13,270	8,250	8,840
Elevation centerline distributor, feet	1,586.67	1,272.0	1,192.0	1,800.53	1,613.49
Elevation centerline runner, feet	1.583.20	1,272.0	1,187.25	1,800.53	1,613.49
Normal headwater elevation, feet	1,650	1,376	1,261.5	1,907.0	1,780.0
Normal tailwater elevation, feet	1,584	1,266	1,194.5	1,805.0	1,614.0

Unit spacing center to center, feet	....	58.0	55.0	....	....
Weight of rotating parts, turbine, tons	14	67.5	43	18	25.252
WR^2 of turbine, pound-foot^2 (million)	0.065	3.7	0.352	0.176	0.25
Shaft diameter, inches (nominal)	18	30	24	19	21
Shaft length, feet	11.16	11.42	15.33	7.22	7.018
Shaft guide bearing diameter, inches	22.75	33.0	25	22.5	22.5
Guide bearing lubrication	Water	Oil	Oil	Grease	Grease
Guide bearing material	Insurok	Babbit	Babbit	Babbit	Babbit
Scroll case	Concrete	Concrete	Concrete	Pl. St. R.	Pl. St. R.
Gate Servomotors:					
Volume, cubic inches	2,720	9,440	7,340	3,500	4,500
Operating, time to open gates, seconds	8	6.0	8.0	8	8
Operating time to close gates, seconds	8	6.0	8.0	8	8
Hydraulic thrust at maximum head and rated speed, pounds	261,000	309,000	482,000	87,500	141,000
Weight and hydraulic thrust, pounds	288,000	444,000	568,000	126,000	191,000
Blade servomotors:					
Volume, cubic inches	....	....	4,320	....	....
Operating time to open blades, seconds	....	....	10.0	....	....
Operating time to close blades, seconds	....	....	10.0	....	....
Type of draft tube	Elbow	Elbow	Elbow	Elbow	Elbow
Turbine manufacturer	Leffel	N.N.	N.N.	Leffel	Leffel
Governor manufacturer	Woodward	Woodward	Woodward	Woodward	Woodward
Generator manufacturer	Elliot	W.	W.	W.	W.
WR^2 of generator, pound-foot^2 (million)	2.3	36.0	13.0	5.6	8.29
Elevation bottom draft tube, feet	1,561.67	1,233.0	1,154.0	1,778.0	1,587.50
Distance centerline unit to end of draft tube, feet	41.0	65.0	65.0	35.0	40.0
Pit diameter (lower)	13′0″	19′0″	19′0″	12′7″	14′0″

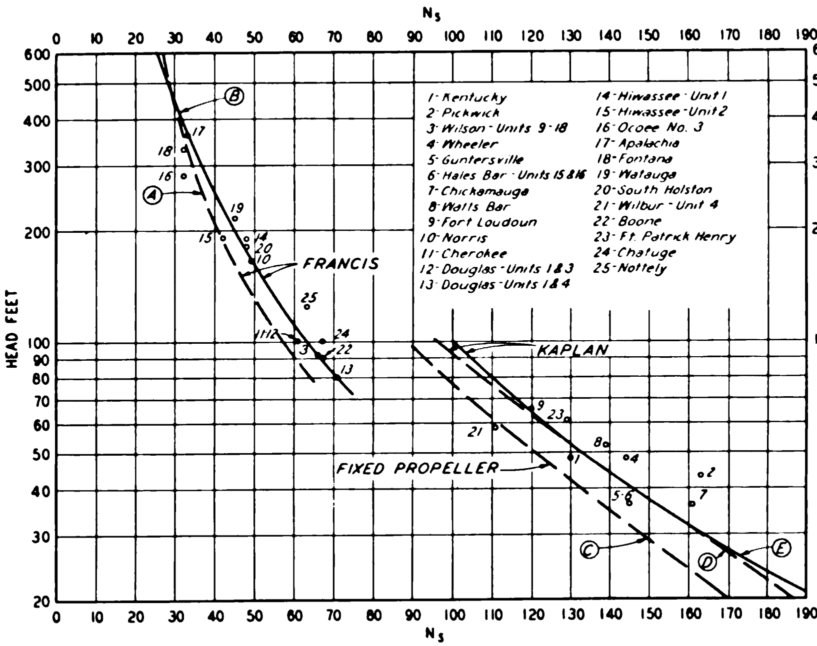

Figure 155.—*Specific speed vs. head—Francis, Kaplan, and fixed propeller turbines.*

In the main river and some tributary plants which operate under low heads and widely varying tailwater elevations, it was necessary, in order to obtain a high enough plant sigma for all conditions of low tailwater, to set the runner below normal tailwater, thus obtaining a negative static draft head. This, of course, results in the wheel being flooded normally and, to gain access to the runner, an unwatering system using pumps was installed. A draft tube water-depressing system also was installed in some of these plants to lower tailwater below the runners to enable the wheels to revolve in air when operating as synchronous condensers. The design of a typical water-depressing system is discussed in chapter 7.

Figure 155 shows the specific speeds of the various TVA-installed units at rated head. The range of values for these units runs from 36- to 360-foot head and from a specific speed of 32 to a specific speed of 163. Also shown in figure 155 are curves of specific speed versus head recommended by several turbine authorities for preliminary selection of specific speed. Curve A is based on the empirical formula $N_s = \frac{5050}{H + 32} + 19$ as proposed by Moody for Francis turbines[1]. A later formula for Francis turbines suggested by White is $N_s = \frac{632}{H^{0.5}}$ as shown by curve B[2]. Curve C shows a specific speed curve suggested by Pfau and White[3] for fixed-blade propeller tur-

[1] Barrows, H. K., *Water Power Engineering*, 2d edition, p. 227.
[2] *Ibid.*
[3] Creager, W. P. and Justin, J. D., *Hydro-Electric Handbook*, 2d edition, pp. 825–828.

bines based on the formula $N_s = \frac{7000}{H + 35}$. They state that the specific speed of an adjustable-blade or Kaplan turbine may be assumed to be 10 percent higher than that of a corresponding fixed-blade propeller turbine. Curve D was made up from this assumption and is based on the formula $N_s = \frac{7700}{H + 32} + 38.5$. Curve E is based on the formula $N_s = \frac{654}{H^{0.4078}}$ which was computed from the average of a number of selected units. Curves B and E form the basis for the turbine speed selection charts shown in figures 156 and 157. These charts are valuable for determination of 60-cycle synchronous speeds for preliminary investigations but, of course, cannot be used for final determination of specific speed.

It will be noted from figure 155 that most of the Francis units lie close to curve B. The Chatuge and Nottely units are instances where it was found more economical to use higher specific speeds than indicated by curve B with the correspondingly higher generator speeds and lower turbine settings.

The Kaplan and fixed propeller units do not follow the specific speed curves as closely as do the Francis units. This can be explained in part by the widely varying headwater and tailwater elevations on the main river plants.

Figure 158 shows the sigma values of the various TVA units at rated conditions plotted against specific speed. Also shown on figure 158 are sigma limit curves for both Francis and Kaplan units proposed by one turbine manufacturer for use when cavitation tests of a homologous model runner are not available. The sigma values lie close together for the Francis turbines but are widely scattered for the Kaplan and fixed-propeller-type turbines. This can be expected when it is understood that the values plotted on figure 158 are for rated conditions only and that the Kaplan turbines operate over extreme head and tailwater variations. Performance guarantees are made to cover these extreme variations.

For example, consider the units at Chickamauga with a contract rating of 36,000 horsepower under 36-foot head, 75 revolutions per minute, with the runners submerged 15 feet below tailwater. This gives a specific speed of 161 and a sigma value of 1.32. These same units, however, are designed to give best efficiency when operating under 48-foot head, under which a maximum output of 42,000 horsepower is guaranteed. Under these conditions the runners are only 7 feet below tailwater, resulting in a sigma value of 0.82 and a specific speed of 121. Actually, when developing the 42,000 horsepower the units are operating at only approximately 75 percent of their possible output. If it were feasible to operate under full-gate conditions at 48-foot head, they would probably develop in the neighborhood of 55,000 horsepower and would have a resulting specific speed of about 140.

The same comments apply to the Pickwick units, which are rated at 48,000 horsepower under 43-foot head but are designed to have their best efficiency when operating between 50- and 56-foot head. If the turbines developed horsepower under the 50-foot maximum

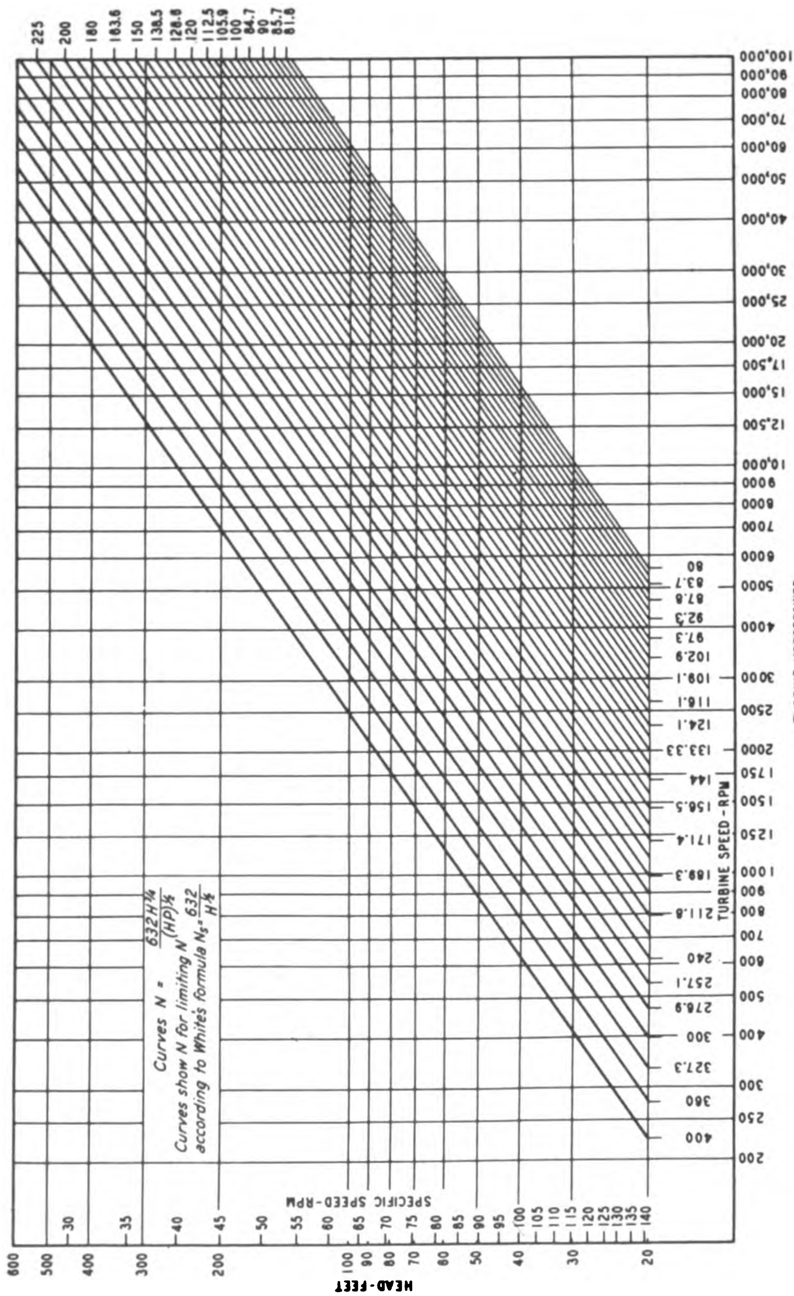

FIGURE 156.—*Speed selection chart—60-cycle snychronous speed—Francis turbines.*

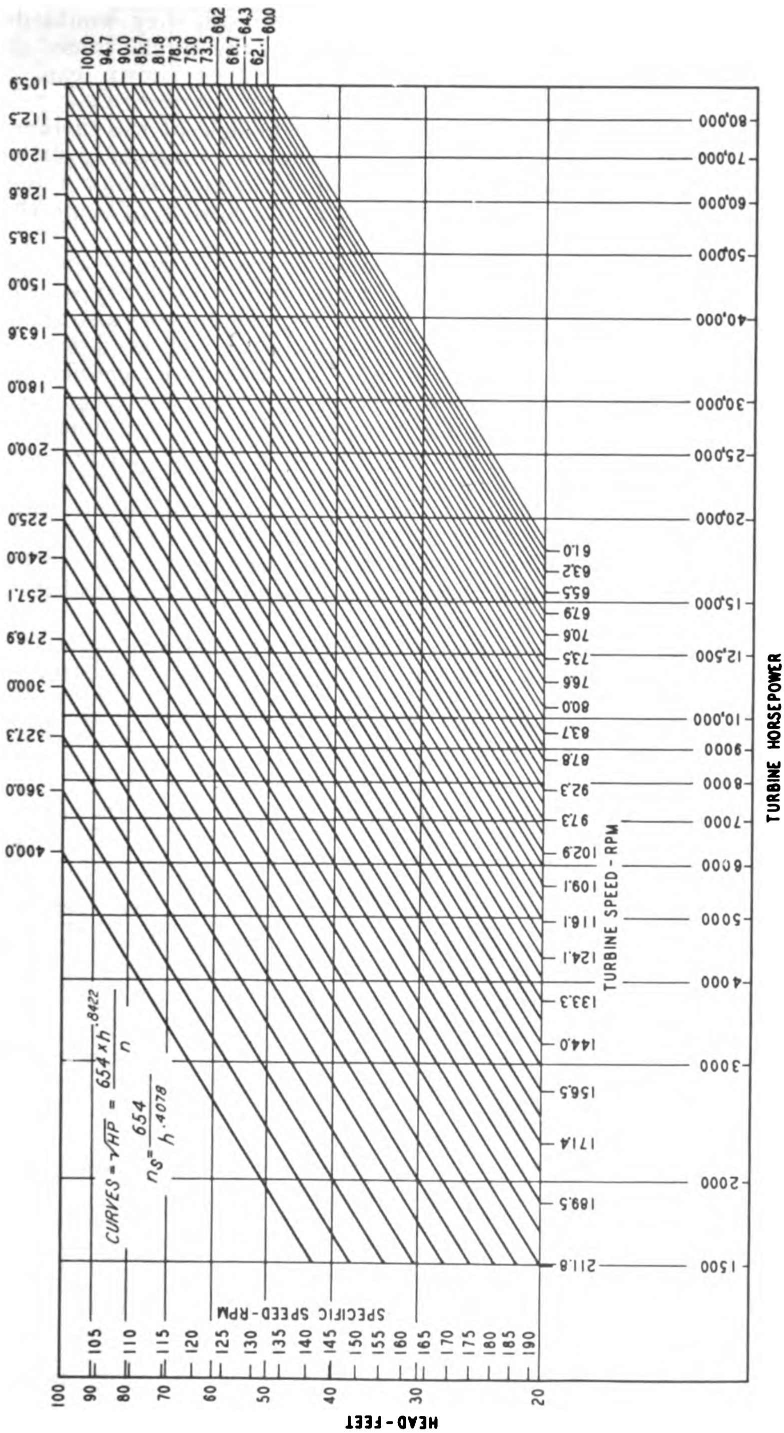

FIGURE 157.—*Speed selection chart—60-cycle snychronous speed—Kaplan turbines.*

head in proportion to their rating at 43-foot head, they would develop about 80,000 horsepower. Consequently, the sigma values are widely scattered, and only the minimum values shown can be considered as critical or limiting values.

In all cases, cavitation tests conducted on models of the turbines, including the complete draft tube and spiral case setting, have shown that the plant sigmas have a safety factor of from 1 to 3 or 4 feet, and operating results to date have indicated the wisdom of using this additional margin to reduce pitting.

To bring out these points more clearly figure 159 shows the specific speeds plotted against the rated heads for 8 propeller type units and, for comparison, for 3 Francis-type units. Figure 159 also shows the horsepower of a 1-foot-diameter runner at 1-foot head for the different Kaplan turbines. This set of points lies close together and indicates that for Kaplan runners, when the head increases from 36 to 65 feet, the allowable unit horsepower per unit of runner area decreases approximately 20 percent. This, of course, agrees with the cavitation theory that the amount of water which can be put through a unit area of runner is limited so the energy in the water leaving the runner shall not be so great that, when regained by the draft tube, it will produce a vacuum approaching the theoretical perfect vacuum of 34 feet of water, less vapor pressure and altitude correction.

As a further check that the turbines selected for each plant conformed to the requirements of good practice as outlined above, the speeds, settings, and sizes of all the units installed in the various TVA projects were coordinated with the various turbine manufacturers before purchase.

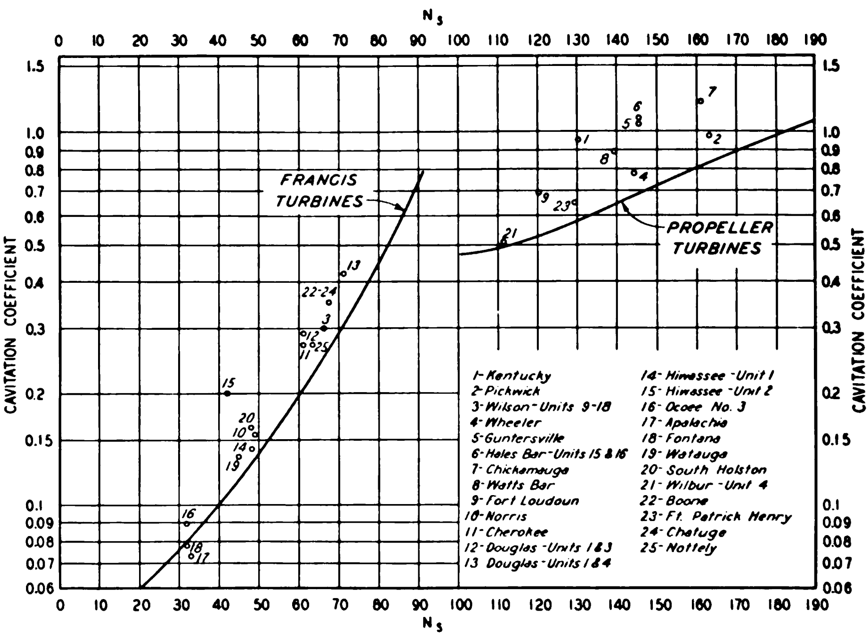

FIGURE 158.—*Specific speed vs. sigma—Francis and propeller turbines.*

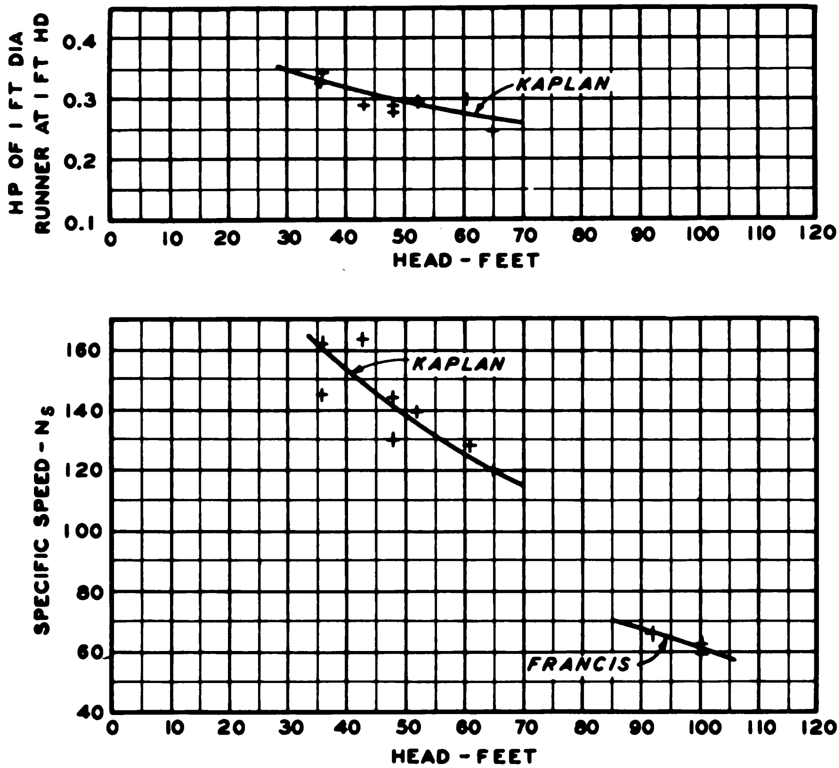

FIGURE 159.—*Turbine characteristic curves.*

DETERMINATION OF SPIRAL CASE AND DRAFT TUBE OUTLINES

In general, the turbine spiral case shape and design vary very little between the various manufacturers. All are spiral type and may be either of circular or rectangular section. In any case, the cost to TVA and the guaranteed efficiencies are very nearly the same for all manufacturers. This is not true with the draft tubes, since there are three distinct types of tubes which are suitable for the turbines that have been installed by TVA. These types are commonly known as the elbow type, the Moody cone spreader type, and the White hydracone (fig. 160).

In selecting the type of draft tube to be used with any given installation, it is necessary to keep the proper perspective between cost and efficiency. Of the three draft tubes mentioned above, the Moody type is probably the most efficient; however, it is by far the most expensive because of the added excavation and the complicated formwork. The White hydracone when compared to the Moody-type draft tube is somewhat less expensive due to the lack of complicated formwork. The excavation is approximately the same for the two types. The efficiency is probably very close to that of the elbow-type tube.

TVA has used the elbow type tube on all its turbine installations, except at Wilson because of the comparatively low cost and completely satisfactory results which have been obtained with this type of tube in the many installations all over the country. The Wilson plant was designed and partially built by the Corps of Engineers, and the Moody type draft tube is used. The elbow type is universally recognized as a standard-type tube, and all turbine manufacturers have model test data on this type, whereas test data on the other two types are limited and probably in some cases entirely lacking.

The usual procedure followed by TVA in laying out the spiral cases and draft tubes in powerhouses is to purchase the generating equipment first, and then give the turbine contractor a free hand within a reasonable limit in the hydraulic design of these water passages. Since the turbine contractor must guarantee the performance of his equipment from spiral case entrance to tailwater, including all losses in those passages, it seems reasonable that he should have some latitude in the design of those passages.

Conditions at Kentucky and Watts Bar Dams, however, made such a procedure impossible. On the moderate head development of this type the powerhouse must form a part of the dam, and the intake structures must be completed to be self-supporting before water can be raised to allow navigation through the completed lock. For both of these projects, Congress had appropriated funds for the construction of a dam and lock without appropriating money for generating equipment. However, the growth of load on the generating system during 1940 and 1941 indicated that only a short time would elapse before generating equipment would be required in both plants.

Prior to this time, each of the three major builders of Kaplan-type turbines had different ideas as to the shape and relative dimensions of both the spiral case and draft tube passages. Two of these manufacturers had a strong preference for splitters in the draft tube. One manufacturer based his designs on a larger-diameter runner with lower water velocity. In order to proceed at Kentucky and Watts Bar with the design of the substructure and to be able to complete the intake structure and enough of the powerhouse substructure to make the intake stable under full headwater pressures, it was necessary to get these manufacturers to agree on a compromise design on which they could all bid to advantage, and in which their machinery would operate, not only satisfactorily, but creditably after installation.

After considerable consultation, a tentative design was agreed upon which the three manufacturers felt would be reasonably satis-

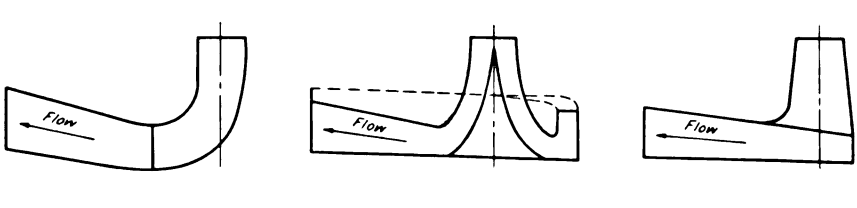

Figure 160.—*Types of draft tubes.*

factory. This design gave each manufacturer certain leeway with regard to the height of wicket gates, the diameter of the stay ring, diameters of the runner, and the exact location and position of the nose pier at the small end of the spiral case.

To satisfy all three manufacturers that their machinery could operate creditably under these conditions, a testing order costing approximately $3,000 was placed with each one. This covered model tests of that manufacturer's turbine in the proposed setting. The designs had been so thoroughly discussed and agreed upon that all three of the manufacturers gave their unqualified approval to the turbine setting after completion of the model tests. Coordination between TVA and the contractors in having the design agreed upon several months before funds were available resulted in a saving of at least 8 months in the time required to put the Kentucky and Watts Bar units into operation.

Conditions at the Watauga plant were such that TVA desired to complete the powerhouse drawings prior to awarding a contract for the generating equipment. To do this work, it was necessary that a draft tube which would be acceptable to all turbine manufacturers be provided. Therefore, TVA invited the comments of the various manufacturers upon a proposed layout, with specific attention to be paid to the proposed draft tube. After many exchanges of requirements and suggestions between the manufacturers and TVA's engineers, a suitable draft tube outline was obtained which could be used creditably with any manufacturer's turbine.

CONTROLS

Plants built by TVA during its first few years were arranged for manual control and operation by a full complement of operators and servicemen. This method of control was universally practiced by all power companies for almost all stations of any importance. The few exceptions to this rule were mostly float-controlled run-of-river plants in remote locations.

In 1941 TVA in a radical departure from the manually controlled station, completed Ocoee No. 3 plant which was remotely controlled from the Ocoee No. 2 station. The distance between these two points is approximately 7 miles and the selected control items were wired from Ocoee No. 3 to Ocoee No. 2. At the time of this installation the 33,000-horsepower machine at Ocoee No. 3 was the largest remotely controlled unit in the world.

In 1949 TVA completed the Watauga plant which is remotely controlled by wire from the main control room some 500 feet from the plant. Since 1949 TVA has completed 7 new stations which are remotely controlled and has changed the controls on 9 existing stations from manual to supervisory, that is, controlled from the control room. Four of these 16 stations are controlled by carrier current. The remaining 12 are wired.

Remote control operation is described in more detail in chapter 4 "Governors." Aside from the remote control of the units there are certain functions normally performed by the turbine operator which must be made automatic and certain safety devices which must be added to any remotely controlled unit.

Greasing of the wicket gate mechanism, which is done by the turbine operator at attended plants, is accomplished at the remotely controlled plants by the automatic greasing equipment described later in this chapter.

On all remotely controlled units automatic generator brake applicators are installed. This device is triggered by a 50 percent speed switch and applies the brakes intermittently for a selected time, then continuously until the unit has stopped rotating.

Additional turbine safety devices provided for remotely controlled units include automatic wicket gate locks, described later in this chapter under "Wicket gates," turbine bearing temperature alarm and shutdown, turbine bearing oil low-pressure or low-level alarm and shutdown, cooling and seal water low-flow alarm and shutdown, greasing system failure alarm, and turbine pit high-water alarm.

CONDENSING FACILITIES

As mentioned previously in this chapter, the turbines in most of the main river and some tributary plants are set with their runners submerged below normal tailwater. To save power when these units are operating as synchronous condensers to regulate voltage and correct power factor, TVA has installed water-depressing systems which lower the water below the runners, thus enabling the wheels to revolve in air.

The usual time required to motor a unit is less than 1 minute. Kilowatt input to the generator, when motoring, varies from 600 to 1,500 kilowatts, depending upon the blade tilt of the Kaplan units, and the physical size of the runner involved. Details of the water-depressing systems are described in chapter 7.

MECHANICAL DETAILS

Runners

TVA has adopted cast steel as the metal for all heavily stressed parts, including all turbine runners. Two types of runners—Francis and Kaplan—are shown in figures 161 and 162. The 8 original 35,000-horsepower units at Wilson Dam are equipped with cast-iron runners, but the 10 new units installed by TVA are equipped with cast-steel runners. While the first cost of the cast-steel runners is greater, cast steel has the ability to resist shocks and avoid the tendency to crack and disintegrate after years of operation when subjected to fluctuating loads.

Cast steel has a much greater resistance to pitting and may be welded in a horizontal, vertical, or overhead position with either mild- or stainless-steel welding rod without having to be drilled and tapped for studs on close centers as is almost a necessity when attempting to fill in pitted areas on cast-iron runners. While bronze is also an excellent metal to resist pitting on turbine runners, pitted areas can only be filled in by a brazing process in the horizontal, or nearly horizontal position, and the entire casting must be preheated to achieve satisfactory results.

Cast stainless steel is not used for two reasons—first, the cost is excessive, and second, the method of prewelding stainless steel to

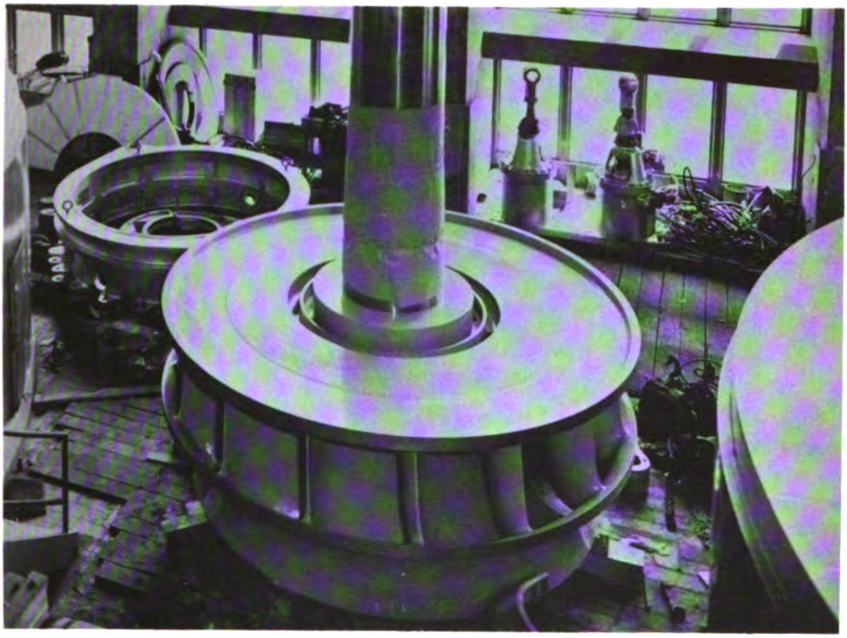

FIGURE 161.—*Typical Francis runner—Fontana.*

cast steel has proved perfectly satisfactory from a cavitation standpoint.

The turbine specifications require that areas subject to cavitation, as shown by experience, be covered with stainless steel welding not less than ⅛-inch thick deposited by not less than two passes and that the surface of the runner buckets or blades be ground smooth to remove all bumps or depressions which would tend to disturb the flow of water through the runner.

Figure 163 shows the developed surfaces of a typical Kaplan blade with the areas normally covered by stainless steel indicated. In cases where pitting occurs outside the area covered by stainless steel the pitted areas are field-welded with stainless welding rod and ground to the original blade contour.

Francis runners are provided with renewable wearing rings where close running clearances occur between the runner band and the stationary parts. These rings are water lubricated and cooled to prevent overheating and consequent seizing.

Axial flow, propeller-type runners are equipped with 5 or 6 blades, depending upon the manufacturer's design. All the earlier units were equipped with sleeve-type bearings. This required relatively large servomotors to overcome the high friction load. The last two units at Pickwick and the two units at Fort Patrick Henry are equipped with roller bearings, and test results indicate perfectly satisfactory operations with greatly reduced friction loads.

The total thrust due to the weight of the rotating parts and the hydraulic thrust is of importance in determining the size of the thrust bearing. The weight of the rotating parts is composed of

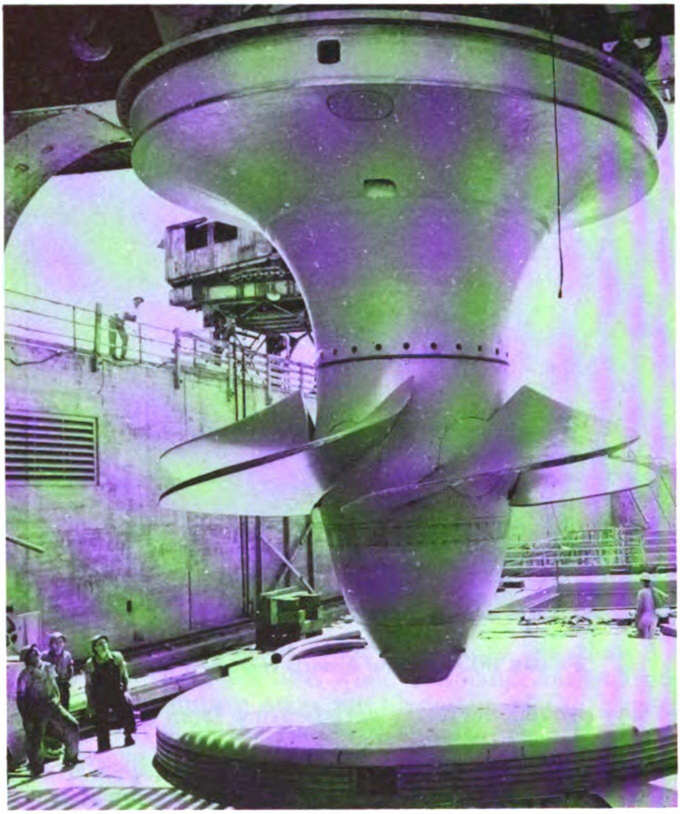

FIGURE 162.—*Typical Kaplan runner—Fort Loudoun.*

the weights of the turbine runner, the turbine and generator shafts, and the generator rotor. The hydraulic thrust is dependent upon the size and type of the runner, and the head under which it operates. The hydraulic thrust can be calculated from the formula $T=\frac{K\pi D^2H}{9.24}$. Figure 164 gives the recommended values of K for use when test data are not available as well as the thrust coefficients for the various Francis units installed by TVA. These coefficients are based on inlet diameters and were computed from thrust values furnished by the turbine contractors.

Wicket gates

Wicket gates are steel castings and when they rotate in the bushings with grease lubrication there is a tendency for the grease to be squeezed out on the loaded side of the bearing which causes corrosion or rusting to occur on these areas. Experiments have been conducted with various types of grease in an effort to find a lubricant which will adhere to the metal surfaces and resist any washing action of the water. There is, however, always some danger of corrosion of these parts.

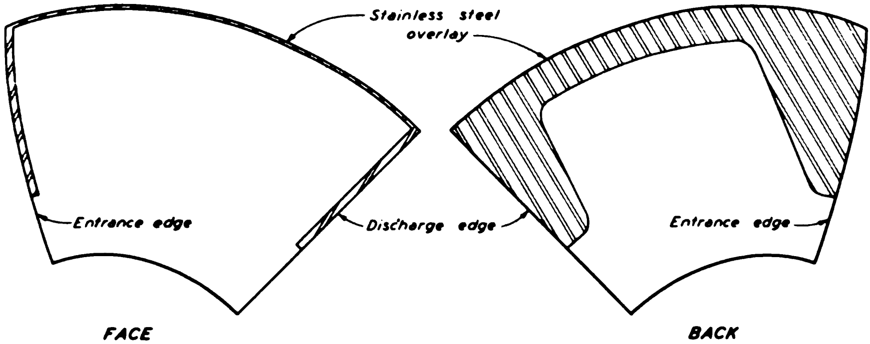

FIGURE 163.—*Stainless steel overlay on Kaplan blade.*

On the high-head turbines, it has been found advisable to add a sleeve or bushing of corrosion-resistant metal shrunk onto the upper and lower wicket gate journals, as well as a stationary bushing in the head cover and discharge ring in which the wicket gate journals rotate. The sleeves on the wicket gate stems may be of stainless steel or of bronze, but if bronze is used a different grade from that used in the stationary bushings should be selected to prevent the scoring which always occurs when similar materials are used. It has also been found advisable on the high-head turbines to apply a strip of corrosion-resistant steel to the top and bottom of the wicket gates and to the adjacent stationary parts, and also on the contact edges where adjacent wicket gates touch each other in the closed position.

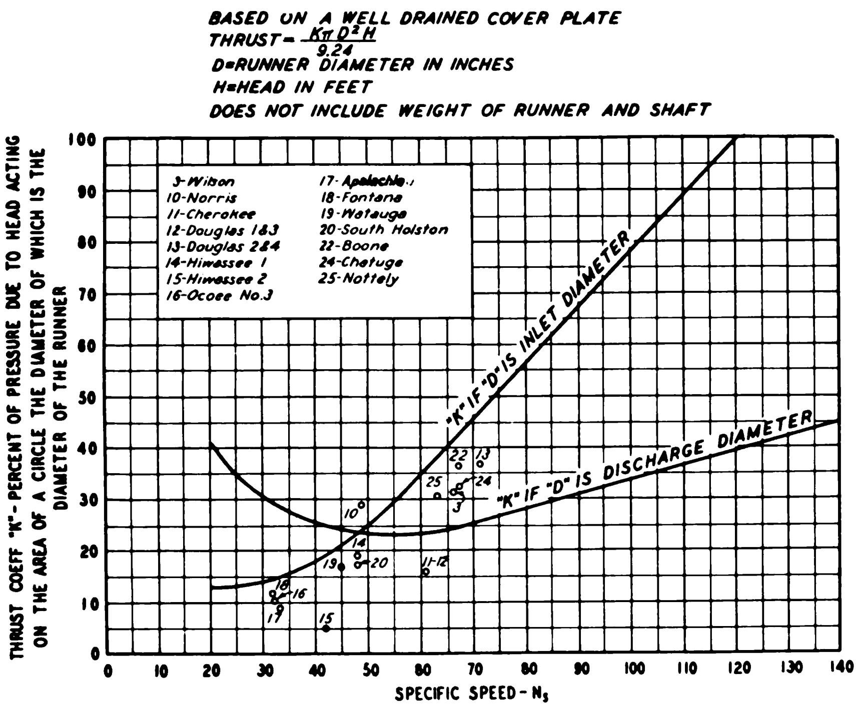

FIGURE 164.—*Hydraulic thrust chart—Francis turbines.*

The majority of the tributary plants of TVA have relatively large storage reservoirs which—except when necessary to store floodwaters—are maintained at low levels during January, February, and March, the only season of the year during which extreme valley-wide floods might occur. The normal cycle calls for filling these reservoirs between January 1 and about June 15, the length of this period depending upon whether it is a wet or dry year, and with filling held to a very slow rate during the flood season. During portions of this period, some of the storage plants will not produce any energy; but at least one unit in each of these plants will be kept floating on the line with guide vanes closed and with water in the scroll case, and with governor set to open the guide vanes and pick up full load in from 5 to 12 seconds in case of trouble on the transmission lines or in case of a slight drop in frequency.

When high-head units are motored, there is bound to be a slight leakage both at the bottom and top of the guide vanes and where they contact each other in the closed position. This may cause erosion similar to a scouring action, or in some cases it causes actual pitting just downstream from the contact edges. At Apalachia a strip of stainless steel about 2 inches thick was welded on the top and bottom of the guide vanes and on the stationary parts adjacent to the ends of the vanes.

The Fontana turbines which operate under a rated head of 330 feet were manufactured during World War II when it was impossible to obtain stainless steel for this purpose. In addition it was desired at Fontana to protect the gate surfaces where they contact adjacent vanes in the closed position. As an alternate to stainless steel, the manufacturer plated these areas with chromium by the electrolytic process, using a low-grade ore which was not restricted. The chromium was deposited a minimum of 0.005 inch in thickness and polished. This plating was also applied to the wicket gate stems, where, under normal conditions, stainless steel sleeves would have been used. After several years' operation the plating appears to be in perfect condition.

In the case of the low-head Kaplan- and propeller-type turbines, where the clearances between the ends of the wicket gates and stationary parts can be as much as one-sixteenth inch or more without causing excessive leakage, plating with corrosion-resisting steel has not been found necessary.

The wicket gates for all plants are designed for operation through a system of links, levers, and a gate ring located on top of the turbine head cover which can be serviced in the dry. The turbine specifications require that all gates be proportioned so that with zero pressure in the opening or closing direction, they are stationary at approximately 30 percent open. Also, each gate with its top and bottom stem is required to be an integral casting.

On units which are remote-controlled the gate mechanism is equipped with an automatic locking device designed to mechanically lock the gates in the closed position at any time the unit is shut down. The gate lock is operated by a small hydraulic cylinder which is actuated by oil from the governor pressure tank. It is controlled by a solenoid located in the governor cabinet and is so

arranged that it will not release the gates unless the governor oil is up to normal operating pressure.

Spiral cases

Spiral cases on the low-head main-river plants are concrete. The high-head storage plants on the tributaries have riveted plate-steel spiral cases of the conventional type, except Apalachia which has a cast-steel spiral case, and Fontana, Watauga, and Hiwassee unit 2, which have welded-steel spiral cases. Because of the comparatively recent practice of using all welded spiral cases and the lack of comprehensive data on this type of casing, TVA requires a hydrostatic test on the completed casing equivalent to the maximum possible head plus pressure rise.

Recently TVA has required that steel spiral cases be subassembled in the turbine manufacturer's shop into sections as large as can be conveniently shipped and handled in order to minimize the number of field joints required. This practice not only reduces the amount of costly field work required but also allows large sections of welded spiral cases to be furnace-annealed. On recent welded spiral cases the field welds have been stress-relieved by a low-temperature flame stress relieving process. Figure 165 shows an all-welded spiral case after field welding has been completed. Figures 166 and 167 show cast steel and riveted steel spiral cases respectively.

All spiral cases are provided with Winter-Kennedy type taps for use with the turbine flowmeters.

Steel scroll cases are painted. For this work TVA has used three different paints—hot bitumastic, red lead, and underwater gray. Hot bitumastic paint has not proved very successful because the coating peels very badly. Red lead is satisfactory only for a short period when used under water. Experience with underwater gray at the end of 10 years indicates that this paint is superior to the

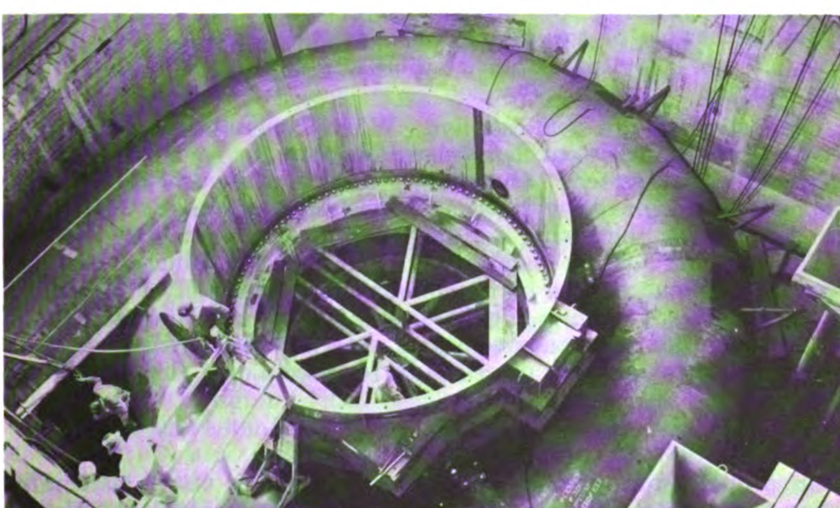

FIGURE 165.—*Welded steel spiral case—Fontana.*

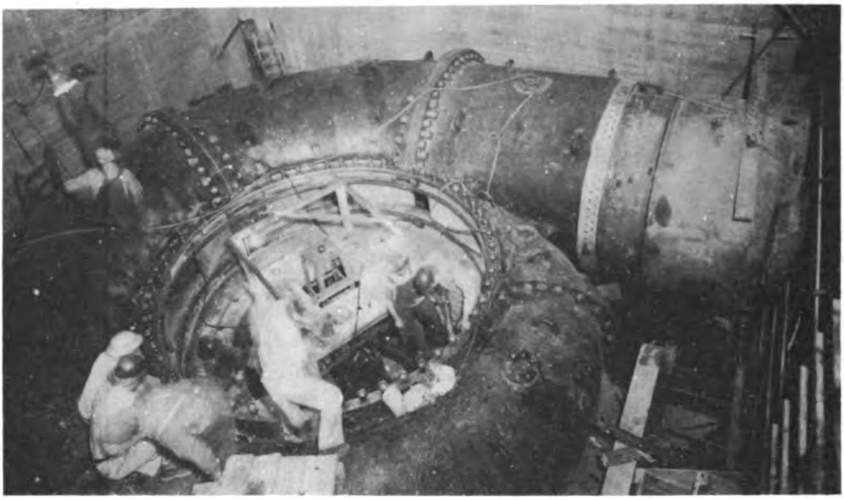

FIGURE 166.—*Cast steel spiral case—Apalachia.*

others, since it does not deteriorate under water and does not flake off. It is less expensive than bitumastic and much more easily applied. Specifications now require that all new units be painted with underwater gray.

Draft tube liners

TVA requires that each turbine be fitted with a draft tube liner extending 8 to 12 feet below the bottom of the throat or discharge ring. The liner is fabricated from rolled steel plate and is intended to cover only the areas immediately below the runner which would be affected by high velocity water leaving the runner. No trouble has been encountered with scouring or erosion of the concrete parts below the bottom of the liner.

Stay rings

The stay rings are steel castings. Where concrete spiral cases are used, the top and bottom flanges are designed for connecting to the surrounding concrete. Where steel spiral cases are used, these flanges are designed for riveting or welding, or, in the case of a cast spiral case, the casing and stay ring are cast integral.

The top and bottom flanges are connected by columns cast integrally with the flanges or by columns cast separately and welded to the flanges. Columns and flanges are shaped to offer the minimum amount of resistance to water entering the turbine. Figure 168 shows a stay ring in place ready for erection of the spiral case to begin.

Discharge rings

On propeller units rolled plate steel has shown itself materially better for pitting resistance than cast steel. In 1 plant containing 4 duplicate units, 2 of the units are equipped with cast-steel dis-

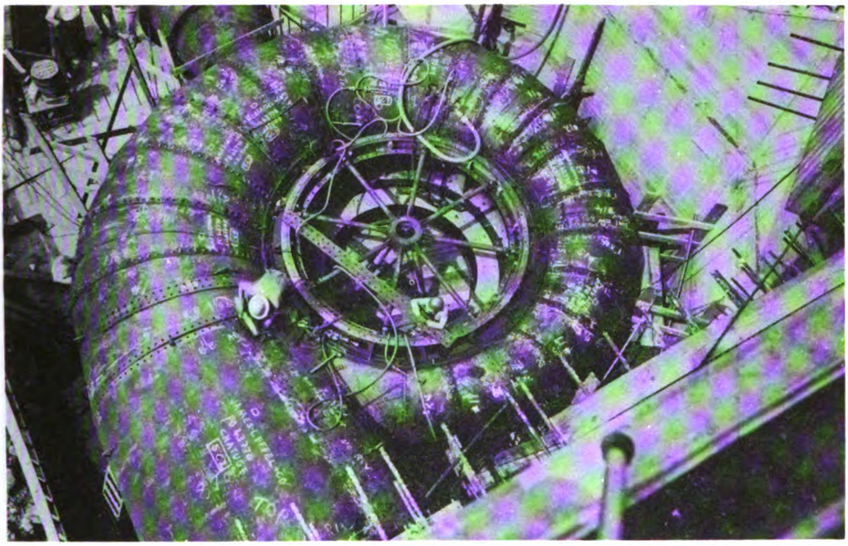

FIGURE 167.—*Riveted steel spiral case—Chatuge.*

charge rings; the other 2 are equipped with plate-steel discharge rings of welded construction. After 2 years of operation, the cast-steel rings had pitted from 1/8 to 1/2 inch deep completely around the ring and approximately 10 inches in height. After 1 1/2 years' operation, the plate-steel rings were still in perfect condition. In another plant where all the discharge rings are welded rolled steel construction there is no evidence of any pitting or erosion after 3 years of operation. TVA's practice is to specify rolled steel welded type discharge rings on all Kaplan- and other propeller-type turbines, but during World War II, restrictions of the use of heavy rolled steel sections forced the manufacturers to change over to cast-steel rings on two of the turbines. Since the lower part of the discharge ring has a spherical shape to fit the curved periphery of the runner blades, plates 4 to 5 inches in thickness are required, and plate steel for these sections was impossible to get under war conditions.

On the majority of installations some pitting has occurred on these rings in the vicinity of the centerline of the runner. This condition has not been serious enough to justify that this area be pre-welded with stainless steel.

Main guide bearings

The units in the main-river plants all have water-lubricated main turbine bearings because these bearings are all located below normal tailwater and are subjected to flooding. Two of these units are equipped with lignum-vitae bearings of the adjustable type, two are rubber-lined non-adjustable type, and the balance, which are in the majority, are the Insurok adjustable type. The Insurok strips are wedged into adjustable shoes which can be adjusted to take up the wear. The bearing surface on the shaft in all cases is a stain-

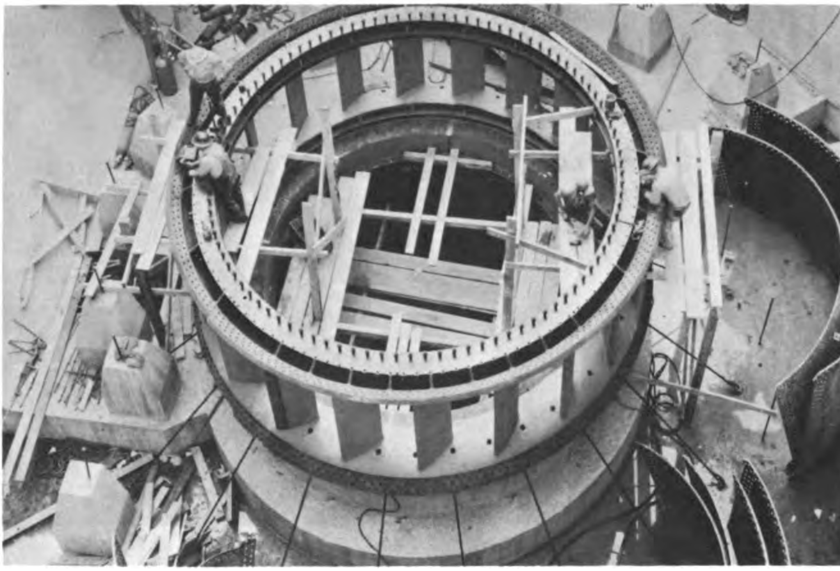

FIGURE 168.—*Stay ring in place—Douglas.*

less or high chromium corrosion-resistant steel sleeve, either pinned or clamped on the shaft with keys.

All the units in the storage or tributary plants have oil- or grease-lubricated babbitt-lined turbine bearings working directly on the polished steel of the main shaft, with one exception: No. 4 unit at Wilbur has a water-lubricated bearing arranged as outlined above for the main-river plants. Oil lubrication at the tributary plants was used because their bearings are located well above normal tail-water and are not normally subjected to flooding. No sleeves are required in these bearings, although corrosion-resistant sleeves are used in the watertight stuffing box below the oil-lubricated bearings.

The lubricating system on the oil-lubricated bearings consists of one alternating-current and one direct-current motor-driven circulating pump. Under normal operation, the alternating-current-driven unit does the work, with the direct-current battery-operated unit as a reserve ready to come into operation in case of low flow or low pressure on the oil-circulating system. An oil reservoir in the head cover is provided for the oil leaving the bearing and gives sufficient cooling to prevent overheating of the oil.

During the past two decades experience with water- and oil-lubricated bearings has gradually changed TVA engineers' thinking with respect to these bearings and their relative merits. Originally it was thought that any bearing subject to constant flooding from tailwater would be less likely to give trouble if it could use water as a lubricant. This has not proven to be the case in that in most hydro plants the station service water is taken directly from the scroll case and any abrasive material in suspension in the water is passed through the bearing. At one plant this condition was sufficiently serious to warrant the installation of a filtered water system to supply the bearings with clean water. The effect of abrasives

in the river water has been noticed at all plants equipped with water-lubricated bearings. As a result of these abrasives in the bearing lubricating water with the attendant high maintenance cost, TVA has stopped specifying this type bearing on new plants.

In an effort to further simplify the turbine guide bearing lubricating system, the Chatuge and Nottely plants are equipped with grease-lubricated bearings, using the same grease as is used on the other turbine parts. The grease is applied by an automatic greasing system and excess or waste grease is automatically dropped into the draft tube below the runner.

Unit guide and thrust bearing

The combination thrust and guide bearing located below the generator rotor is considered an electrical design feature and as such is covered in the second volume of technical report No. 24, *Electrical Design of Hydro Plants*, both in chapter 4, "Generators," and appendix A, "Generator Specification and Data." Because of the importance of the combination thrust and guide bearing to the unit as a whole, the discussion under "Bearings" in chapter 4 of that volume is given in full as follows:

A combination thrust and guide bearing located below the rotor is specified, but an additional guide bearing above the rotor is permitted if it is desired by the manufacturer. Upper guide bearings were used by one manufacturer on 13 generators at Kentucky and Wheeler, as mentioned previously in this chapter. All other generators have only the combination thrust and guide bearings below the rotor.

Kingsbury type, flat thrust bearings manufactured by Kingsbury Machine Works or by Westinghouse Electric Corp. were used on all generators up to May 1949 except the first two at Wheeler, which were General Electric spring type. The Kingsbury type had a smooth rotating runner plate and several stationary babbitted shoes, each of which was supported at about its center by a spherical-ended, hardened jack screw. This arrangement provided solid support for the shoes, adjustment for plumbing the shaft, and adjustment for loading the shoes equally. Equalizing Kingsbury bearings, in which the shoes rest upon an assembly of equalizing levers instead of upon rigid jack screws, were investigated several times; but the advantages were not considered sufficient to justify the greater complication. The General Electric spring bearing also had a smooth rotating runner plate; but instead of separate babbitted shoes, it had a thin, flexible stationary babbitted plate supported on a large number of springs. The springs were precompressed by axial bolts sufficiently to provide a sensibly solid support if all the springs were uniformly loaded, but they presented some degree of yield if loaded nonuniformly. The shaft was plumbed by jack bolts at the corners of the bearing bracket.

By 1949, when Gunterville unit 4 was purchased from the General Electric Co., the spring bearing had been improved by using separate babbitted shoes or stationary segments. It was accepted by TVA for this unit and also for the two new units at Hales Bar, two additional units at Cherokee, and one at Douglas.

Recently, as just mentioned, the design of the General Electric type bearing has moved definitely toward the design of the Kingsbury type. The Kingsbury design, particularly as made by Westinghouse, has also moved somewhat toward the General Electric design, and eventually each may have the best features of both. These improvements include: a larger number of shoes, jack screws supported more resiliently, better means of measuring the loadings on the various shoes, shoe supports designed to spread the loading more uniformly over the contact area, and temperature detectors placed closer to the bearing surfaces.

The guide bearing used on most of the generator is of the multiple-shoe, babbitted type capable of adjustment as to diameter and as to center. The thrust and guide bearings are located in a common oil reservoir cooled by water coils.

Main shaft

All shafts are open-hearth carbon- or alloy-steel forgings, heat-treated, and smooth-machined finished. They are fitted with renewable sleeves, keyed or screwed to the shaft, where they pass through the water-lubricated guide bearing and the stuffing box in the head cover. All are hollow bored and given internal inspection to detect any flaws or cracks. Flange details, such as flange diameter and thickness, number and size of bolts, and bolt holes, jack bolts, rabbets, relief, etc., are in accordance with ASA Standards.

Francis and fixed propeller blade units require conventional shafts of standard proportions. Shafts for Kaplan turbines are not of standard proportions since the upper part of the shaft has a cylindrical bulge which contains the servomotor for operating the runner blades. This bulge may or may not be an integral part of the main shaft. The main body of the shaft is larger than would normally be required since the operating piston rod is contained in the main shaft.

Wicket gate operating mechanism

All turbines are provided with a wicket gate operating mechanism which is located inside the turbine pit and consists of two servomotors, the gate ring, and the wicket gate links, levers, arms, and shear pins. The servomotors are held rigidly in place from bases provided in the pit liner. The entire mechanism is designed so that each servomotor applies approximately equal forces upon the gate ring in either the opening or the closing direction. The links and levers are connected by an eccentric bolt which allows individual adjustment of each gate and ensures that all gates open and close equally. Each gate is protected by a breaking link or

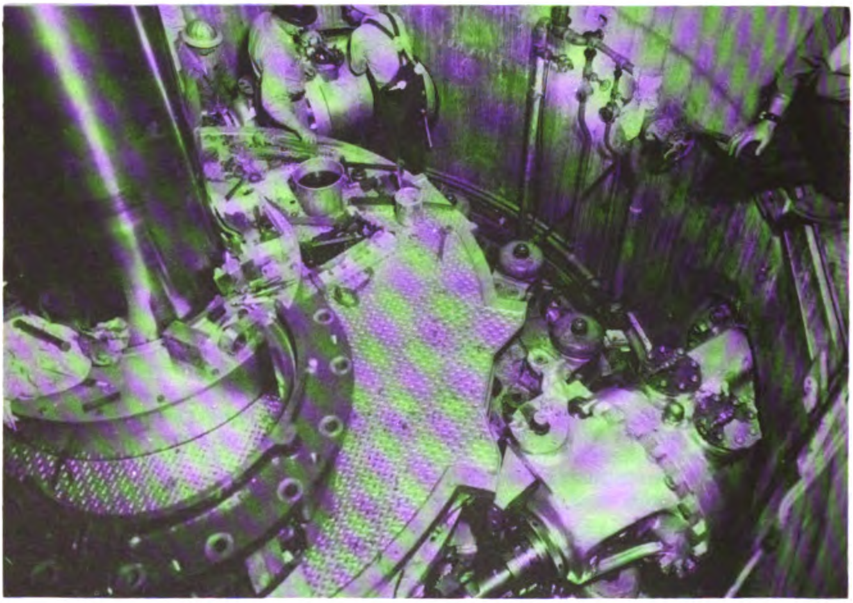

FIGURE 169.—*Assembling servomotors and lever arms—Fontana.*

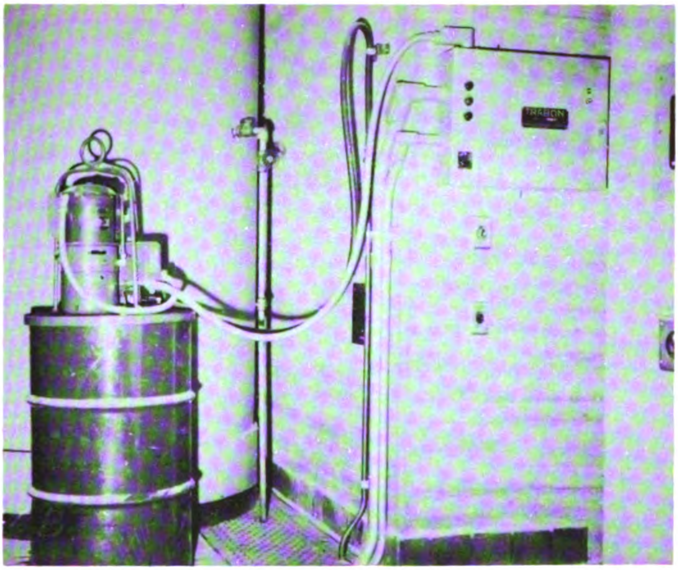

FIGURE 170.—*Typical automatic grease pump and control box—Chatuge.*

pin which is designed to break in case foreign material becomes lodged between the gates, thus preventing damage to the rest of the mechanism. The entire gate-operating mechanism is oil-operated by the servomotors which are connected by pressure piping to the governor oil pressure systems. Figure 169 shows the servomotors and gate operating mechanism for Fontana unit 3 being assembled.

Greasing systems

All turbines are equipped with a grease lubricating system of either manual or automatic type. The first plant to be equipped with an automatic system was the Watauga plant. All new plants since Watauga have been equipped with automatic systems and as other plants are modernized automatic systems are added.

The automatic greasing systems consist of a central pumping station; a control box housing the necessary timers, relays, etc.; master and submaster feeder blocks; solenoid valves; and the necessary piping. Figure 170 is a typical installation showing the grease pump, grease drum, and control box. Figure 171 shows the piping and distributor blocks in the turbine pit.

The pumping unit is driven by a 115-volt single phase, 60-cycle motor, and is so designed that a standard 400-pound capacity grease drum may be used as the grease reservoir. The pumps are designed to operate at pressures up to 3,500 pounds per square inch and have a capacity of 4 cubic inches per minute.

Each greasing system is electrically divided into two separate sections, each controlled by a separate timer. One section supplies grease to the wicket gate stem bearings, shifting ring bearings, and other parts which require a relatively large quantity of grease. The timer which controls this section can be adjusted to start the pump at intervals of from 2 to 24 hours. The other section supplies grease

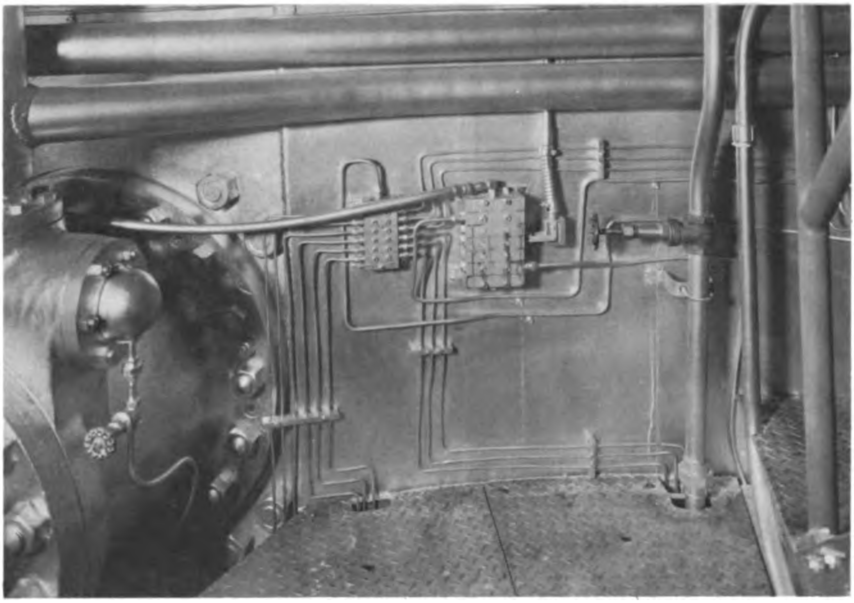

FIGURE 171.—*Automatic greasing system and distributor in turbine pit—Cherokee.*

to the gate linkage pins and other parts requiring only a small quantity of grease. The timer controlling this section can be adjusted to start the pump at intervals of from 1 to 7 days. The time that the pump remains on is also adjustable, which makes the system very flexible in determining the quantity of grease to each section.

Each system is provided with certain safety devices which shut down the pump and sound an alarm in case of a blocked bearing, a broken main line, loss of alternating-current power supply, pump failure, or abnormally high pressure.

METHODS OF PREVENTING CAVITATION

TVA's experience indicates that, while it is impractical to eliminate cavitation entirely, pitting in the turbine runners and stationary parts can be materially decreased, or nearly eliminated by observing carefully the five following major points in design and operation:

1. The turbine runner must be set with proper relation to normal tailwater, and for this purpose accurate cavitation tests on a model are desirable, not only on Kaplan- and fixed propeller-type units, but also on Francis-type units. Such tests give accurate information from which to judge the safe operating limits, both for limiting the horsepower of the unit under critical headwater and tailwater conditions and for determining the proper setting of the runner with relation to tailwater when designing the plant.

2. The turbine parts and the water passages must be properly designed. The major responsibility for this item lies with the manufacturer who must watch the location of the wicket gate pivots with respect to the diameters of the runner so the tips of wicket gates do not overhang the runner sufficiently to cause pitting. He must watch the curve of the throat

ring, as too sharp a curve will result in disturbances which induce cavitation. He must watch the shape and taper of the wicket gates and, in many cases, must reduce the thickness or taper them toward the bottom edge in order not to leave voids in the stream of water entering the runner. He must also watch the clearances between the runner and the throat ring, and the curve of the throat ring and the lower part of the runner, so as to strike the proper balance between efficiency, pitting, and cost in the design of these parts.

3. Suitable materials must be selected. As previously discussed in this chapter, welded plate-steel throat rings offer a great deal more resistance to pitting than cast-steel throat rings. Figure 172 shows one of the cast-steel throat rings on a Kaplan runner turbine after slightly more than 3 months' operation. The pitting starts approximately at the centerline of the runner and extends diagonally downward about 6 inches following the path of the water. This excessive pitting, after only 3 months of operation, was traced to the $\frac{1}{64}$-inch offset between the horizontal joints of the upper and lower sections of the throat ring caused by improper handling of the parts either during shipment or erection. In one or two other cases pitting has been aggravated to a large extent by an obstruction or a small burr on this horizontal joint.

4. Suitable protection must be provided by the use of stainless steel and other corrosion-resistant metals. The practice of prewelding critical areas on the edges and lower surfaces of the runners appears to offer adequate protection, but, even so, cast steel should be used in preference to cast iron so that additional areas can be repaired by welding before pitting becomes dangerous. Figure 173 shows a portion of the area on a Kaplan runner blade which has been prewelded with stainless steel. This photograph also shows the pitted area on the bottom side of the blade after twelve months of operation at practically full load. This pitted area was welded with stainless steel rod before the unit was put back in service. One year's additional service showed practically no additional pitting, and the stainless steel surfaces remained perfect.

5. Operations must be within judicious limits as to capacity and heads, based on the information obtained in the cavitation tests on the model, and from vibration or noise tests on the actual installation. In some instances, it has been found impractical to set the turbine low enough to allow for full gate operation under conditions of low tailwater. Under these conditions, which may occur one or two weeks toward the end of the drawdown period, it has been found necessary to reduce the output of the turbine to loads which the model tests indicated were within the cavitation limits. In many cases, it has been found that the turbine can develop 10 or 20 percent above the rated capacity, especially where the units are subject to considerable variation in head. In some cases also, it is possible to utilize this capacity without overheating the generator.

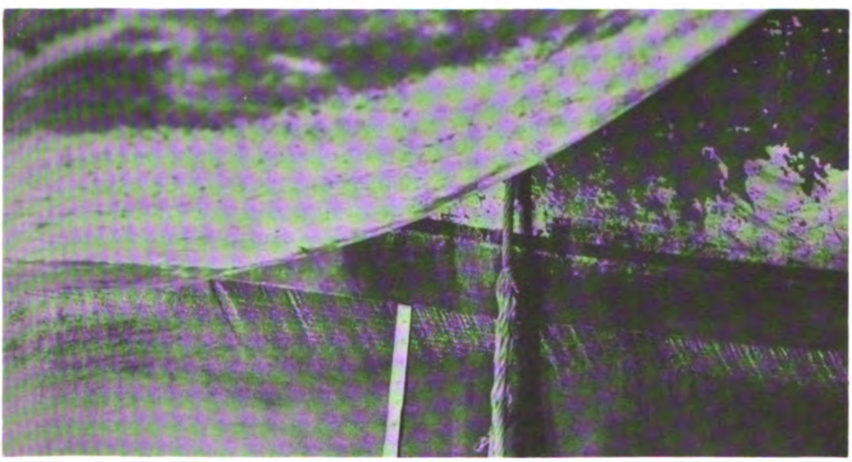

FIGURE 172.—*Cavitation in throat ring—Chickamauga unit 2.*

Sometimes these overloads produce vibration and other disturbances which indicate that cavitation is occurring in some part of the turbine. By maintaining the output just below the point at which these noises and vibrations become objectionable, cavitation and pitting can be materially reduced.

TVA requires the turbine manufacturer to guarantee the runner and throat ring against excessive pitting caused by cavitation for the first year of operation, provided the turbine is operated within a range of power output specified by the manufacturer. The following is a typical cavitation guarantee for a turbine rated at 21,000 horsepower at a net head of 124 feet:

The undersigned bidder hereby guarantees that excessive cavitation will not occur in the runner of the turbine within one year from the date the turbine is placed in commercial operation provided that the turbine is not operated.

1. More than 800 hours during the year at less than the minimum horsepower specified below, or
2. More than 50 hours during the year at outputs greater than the maximum specified below.

Output horsepower		Net head
Minimum	*Maximum*	*(feet)*
10, 240	31, 000	160
8, 460	25, 600	140
6, 940	21, 000	124
5, 620	17, 200	110
3, 930	11, 900	90
2, 340	7, 100	70

The centerline of the distributor will be set at elevation 1613.49 or 0.5 feet above tailwater with a discharge of approximately 1,760 c.f.s. through the unit.

The amount of pitting allowable under the guarantee is usually determined by the following formulas:

1. Francis-type turbine—$W = D^2$
2. Propeller-type turbine—$W = 1.5D^2$

Where
W = Pounds of metal removed
D = Discharge diameter of the runner in feet

FIGURE 173.—*Cavitation on underside of Kaplan blade—Chickamauga.*

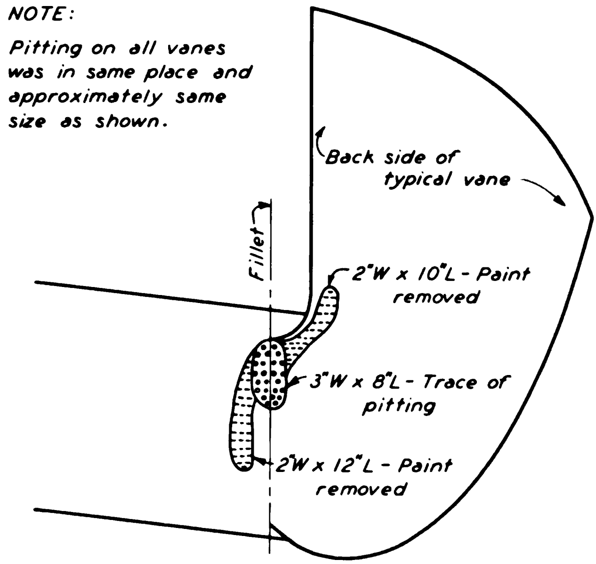

FIGURE 174.—*Cavitation on Francis runner—Cherokee unit 2.*

The turbines are inspected after 1 year of operation to determine if the cavitation guarantees have been met. Figure 174 shows the condition of a typical vane of the Cherokee unit 2 runner after 1 year of operation. Pitting of this runner was slight and practically no metal had been removed.

ERECTION

The erection of hydraulic turbines is preceded by the construction of the powerhouse substructure since the substructure forms the turbine foundation. Embodied in the substructure is the draft tube which is formed according to a design furnished or approved by the turbine manufacturer. Before the turbine erection is started, as much as possible of the substructure concrete is placed. Where concrete spiral cases are used, the concrete is placed up to the spiral case roof. In plants where steel spiral cases are used, the piers between units are usually placed up to the first horizontal construction joint above the top of the casing. In either case a sufficiently large recess is left to install the embedded parts of the turbine. Concrete piers, containing anchor bolts and jack pads of sufficient size and height are provided as a support for the stay ring and spiral case (when of steel) in order that they may be precisely positioned and to provide access to the underside of the parts during assembly.

The turbines are erected by TVA forces under the supervision of an erecting engineer of the manufacturer who furnishes the equipment. The erection of the turbines follows a more or less standardized procedure which consists of the following operations in the order named: (1) erection of the embedded parts, (2) placing concrete around the embedded parts, (3) erection of the internal parts, and (4) alignment of the combined rotating parts of the turbine and generator.

Before any turbine erection work is done a construction specification is prepared outlining the procedure to be followed in erecting and aligning the various turbine parts. This specification is coordinated with the turbine, governor, and generator manufacturers and other interested parties before it is issued. Typical erection specifications for both Kaplan and Francis turbines are included in appendix A.

Embedded parts

The embedded parts usually consist of the following pieces (fig. 175): (1) the draft tube liner, (2) the throat or discharge ring, (3) the stay ring, (4) the scroll case, and (5) the pit liners. They are usually installed in the order named. The various parts as received at the plant site are composed of two or more pieces, depending upon the size of the machine. The component pieces are then assembled together on the job to form the completed part.

The draft tube liner is usually fabricated from rolled steel plates with riveted or welded connections. Sufficient ribs of structural shapes are provided on the outside to ensure a bond with the concrete. The liner is placed in the recess provided and is set to the approximate final position. Anchor bolts and jack bolts are installed and internal bracing if necessary. The liner is then positioned accurately so that the connecting pieces will be in the correct position and so that the bottom of the liner will form a smooth transition from the liner to the existing concrete. To ensure a good alinement job and to provide additional anchorage for the remaining embedded parts, the liner is concreted in before additional parts are assembled. The placing of concrete is limited to 2 feet vertically per hour, and no mechanical vibrators are allowed. Concrete is placed to within approximately 3 feet of the top of the liner. The remaining portion is left exposed to facilitate the erection of the remaining parts.

The discharge ring is made from steel castings or rolled steel, usually in two half sections designed for bolting together. The lower part of the ring is machined and drilled for a riveted or welded connection to the top of the draft tube liner. The top of the ring is machined to receive the bottom flange of the speed ring. In erecting this piece, the two half sections are bolted together on the erection floor and lowered into place on top of the draft tube liner. It is then temporarily bolted to the liner in approximately the correct location. The tie rods and jack bolts for positioning are installed and the ring is then ready for the stay ring installation.

The stay ring casting consists of the upper and lower flanges connected by integral vertical columns. The stay ring is generally made in two or more sections split vertically through the flanges. Each section is cast separately and the ends are machined and drilled for a bolted connection with fitted bolts. Each section is provided with jack pads and bolt holes for erection purposes. The sections are placed separately on the erection pier and are held in the approximate correct location by means of the jacks and anchor bolts. As each section is placed, it is bolted to a previously placed piece. When all pieces are in place, the entire stay ring is then positioned from previously established lines and elevations. This is

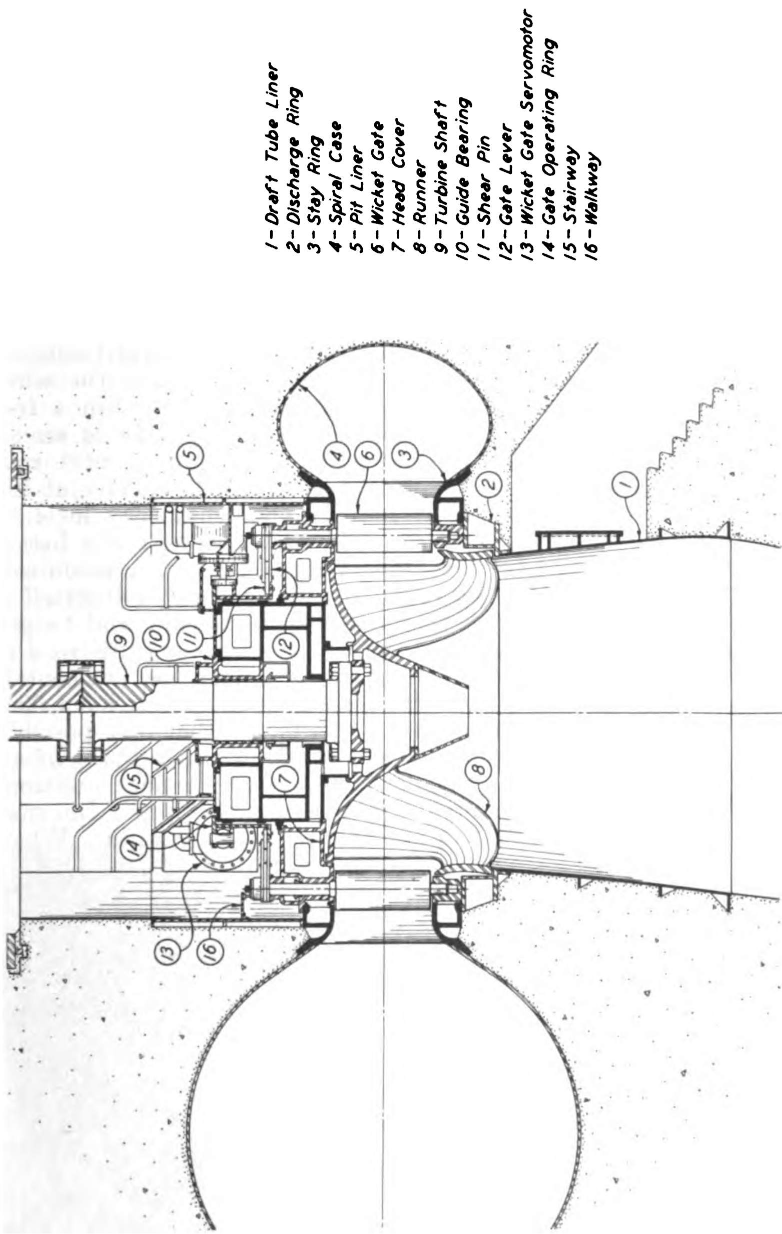

FIGURE 175.—*Section through Francis turbine.*

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accomplished through the use of the supporting jacks and anchor bolts. In addition, the ring is well braced both internally and externally. Figure 176 shows the Cherokee stay ring being erected.

In placing the stay ring, great care is exercised to ensure a good setting since the installation of the remaining parts and the successful operation of the turbine depends to a large extent upon this setting. In setting this ring a heavy plumb bob (75 to 100 pounds) is suspended from a point above the stay ring to a point at the bottom of the draft tube liner. This bob is supported by a small piano wire, and the bob itself is placed in a container of heavy oil. The piano wire is located at the intersection of the longitudinal and transverse unit centerlines by means of an engineer's transit. After the wire is in the correct location, the stay ring is set accurately about the wire by means of trams. These trams are fitted on one end with adjustable micrometers which are arranged so that in conjunction with batteries and headphones an electrical contact is made between the circular part of the speed ring and the wire. Using this method of alinement the ring can be set within a few thousandths of an inch. The elevation of the stay ring is set as nearly correct as possible with an engineer's ordinary level rod. Once the correct elevation is established, the finished surface at the top of the stay ring is leveled by means of an engineer's level or precise transit and a micrometer rod. This rod consists of a heavy metal base (5 to 10 pounds) machined for resting on the machined surfaces of the stay ring. Into the top of the base is inserted a metal rod which has attached to its top a micrometer and target arrangement for sighting by the level. The cross hairs in the target are set at 45 degrees with the vertical and the horizontal, and it is possible for a good operator to consistently detect a 0.002-inch movement of the target height, which means that it is possible to set the entire stay ring level within a very few thousandths of an inch. At the time the stay ring is being set in its final position, the holddown bolts and supporting jacks are made tight. Internal and external bracing is installed and made rigid and tight. When

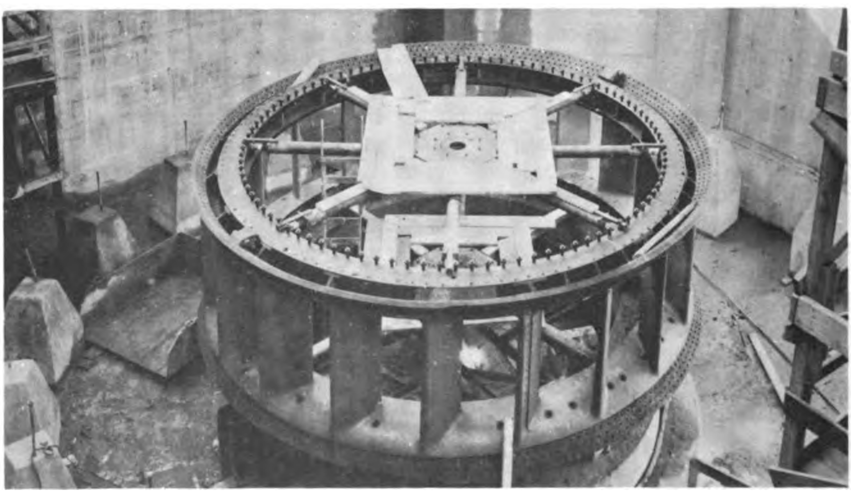


FIGURE 176.—*Setting stay ring—Cherokee.*

the stay ring is in its correct location, the previously installed discharge ring is pulled up under the stay ring and the mating flanges are bolted and doweled. Then the joint between the bottom of the discharge ring and the top of the draft tube liner is made up either by riveting or welding, or both, depending upon the design of the joint. Figure 177 shows the interior of a concrete spiral case with the stay ring in place.

The top part of the stay ring is provided with a flange for receiving the pit liner. The pit liner is made up of comparatively thin plate (3/8 to 5/8 inch), fabricated to the desired dimensions. It is provided with horizontal flanges on top and bottom which are connected on the outside by vertical stiffeners. The lower portion contains the recesses for receiving the wicket gate operating servomotors. The lower flange of the liner is drilled for bolting to the top of the stay ring. After the stay ring and discharge ring are in place, the pit liner is placed upon the top of the stay ring and bolted. Before the liner is secured in the final location, particular attention is paid to the recesses for receiving the gate servomotors. These bases really determine the exact location of the liner, since about the only other function the liner has is to act as a form while placing concrete and to keep seepage water from entering the turbine pit. When the liner is in the correct location, it is well braced both internally and externally so that the alignment will be held during the placing of the concrete.

When the installation of the embedded parts is complete and all parts are properly aligned and braced, the placing of the concrete is started. The concreting schedule is arranged so that the vertical lift due to the buoyancy of the plastic concrete will not raise the embedded parts. The rate of placing is held to not more than 2 feet per hour. In placing the concrete, pours are always made in opposite quadrants so that the side thrust will be equalized and will have less tendency to force the embedded parts out of line. During

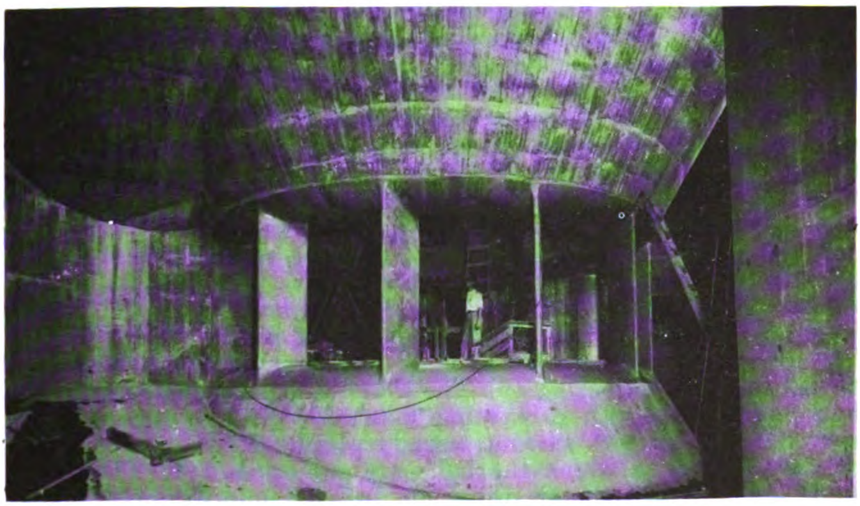


FIGURE 177.—*Concrete spiral case—Watts Bar.*

concrete placing the position of the stay ring is checked daily in both the vertical and the horizontal planes.

When concreting is complete, the interior of the embedded parts is cleared of all bracing, forms, etc., and the mating parts are cleaned and made ready to receive the internal parts.

Internal parts

The internal parts consist of the following pieces (fig. 175): (6) wicket gates, (7) head covers, (8) runner, (9) shaft, (10) bearing housing, (11) shear pin and links, (12) levers, (13) servomotors, (14) shift ring, (15) stairways, and (16) walkways, and are installed as follows: The wicket gates are placed upright on the distributor ring (which may or may not be an integral part of the throat ring). The outer head cover is then lowered into place over the wicket gate trunnions. When the head cover comes to rest on the stay ring flange, each wicket gate is tested separately for free movement. If necessary, the head cover is shifted sideways or rotated until the best position is located. If one or more wicket gates are still tight, the bushing in the head cover or the distributor ring is scraped until the necessary alignment is obtained. The outer head cover is then doweled to the stay ring.

The installation of the remaining parts varies somewhat between a Francis turbine and a Kaplan turbine. For a Francis installation, the runner is placed in the pit and rested upon the ledge at the top of the draft tube. The shaft is then placed on and bolted to the runner. Care is exercised in making this connection to get all coupling bolts tight. Prestressing is accomplished by stretching each bolt to a point approximately 25 percent above the maximum loading to which the bolts may be subjected. The runner is centered in the stationary wearing rings and the shaft is set vertical by means of four plumb bobs. This is checked by an accurate level on the face of the shaft flange. The head cover is then placed around the shaft and on the flange of the stay ring. The bearing housing and stuffing box are then placed around the shaft and on the head cover. The bearing housing is shop doweled to the head cover before the final inside and outside turns are made, thus ensuring a true circle when they are reassembled in the field. These dowels are replaced and the bearing housing and head cover assembly is centered around the vertical shaft, with care being taken to ensure that the bearing has equal clearance at top and bottom. When the correct alignment is obtained, the head cover is bolted and doweled to the stay ring.

For a Kaplan turbine (fig. 178): (1) The runner hub is placed upon an erection pedestal in the service bay. (2) The individual runner blades are inserted in holes provided in the hub and locked in place. (3) The links which connect the runner blades to (4) the cross head are installed and are left hanging to be later connected to the cross head. (5) The shaft is placed upon the runner hub and bolted, with care being taken to prestress the bolts by stretching the correct amount, usually about 25 percent above the maximum load to which the bolts are subjected. (6) The inner shaft and (7) servomotor piston are inserted into the main shaft. The cross head is placed around the lower end of the piston rod

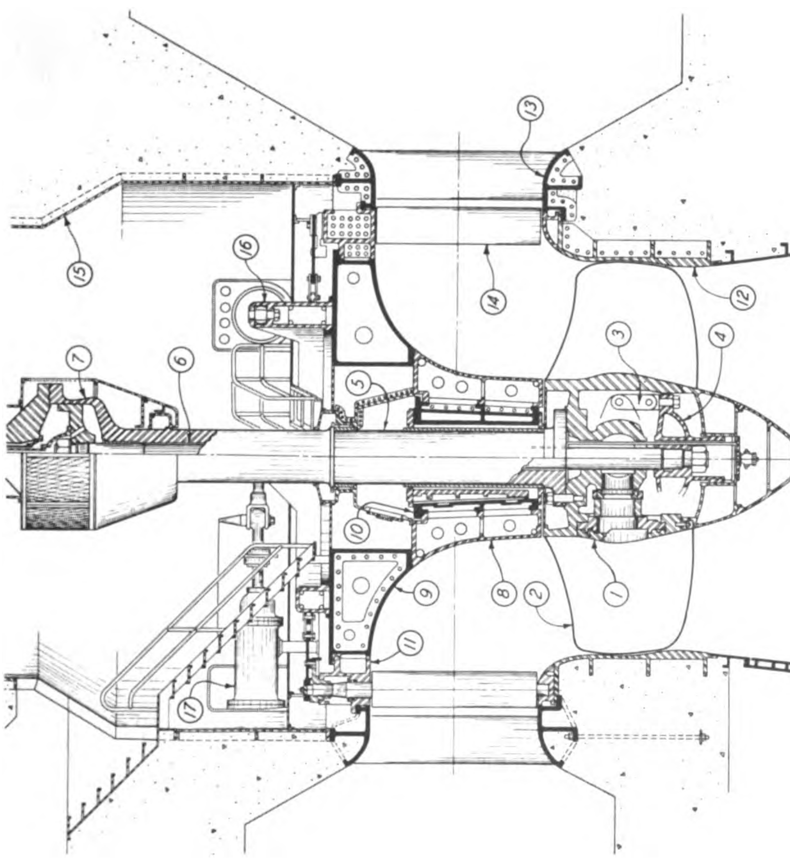


FIGURE 178.—*Section through Kaplan turbine.*

and the connecting link from the blades are attached. (8) The inner head cover is placed around the shaft and on the runner hub. (9) The intermediate head cover is then placed around the shaft and on the head cover barrel (fig. 179). The factory dowels and bolts which align these two pieces are then replaced. The (10) guide bearing housing and runner support are installed and the shaft is wedged in the center of this whole assembly. The entire runner and shaft assembly is then placed in the pit (fig. 180) where the inner head cover is rested on the (11) outer head cover flange. The runner blades are centered in the throat ring and the shaft is set vertical. From the shaft the bearing housing is centered and then the head covers are doweled to each other and to the stay ring.

The gate servomotors are installed in the recesses provided in the pit liner, and the gate operating ring is installed on the head cover. In making the connection between the servomotor pistons and the gate operating ring, care is exercised to ensure a free and equal operating stroke. In connecting the wicket gates to the gate operating ring, care must be exercised to ensure that the eccentric pins provide full closure for each gate.

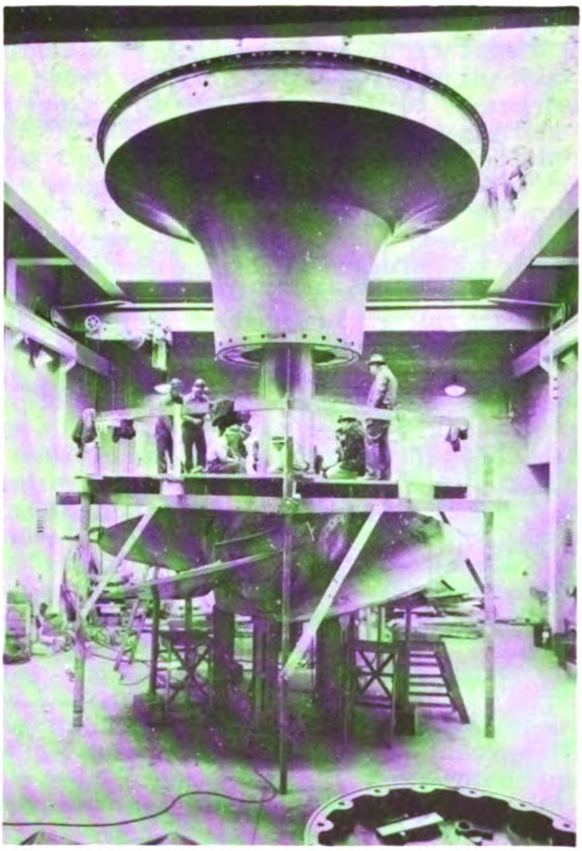


FIGURE 179.—*Assembling Kaplan runner—Watts Bar unit 5.*

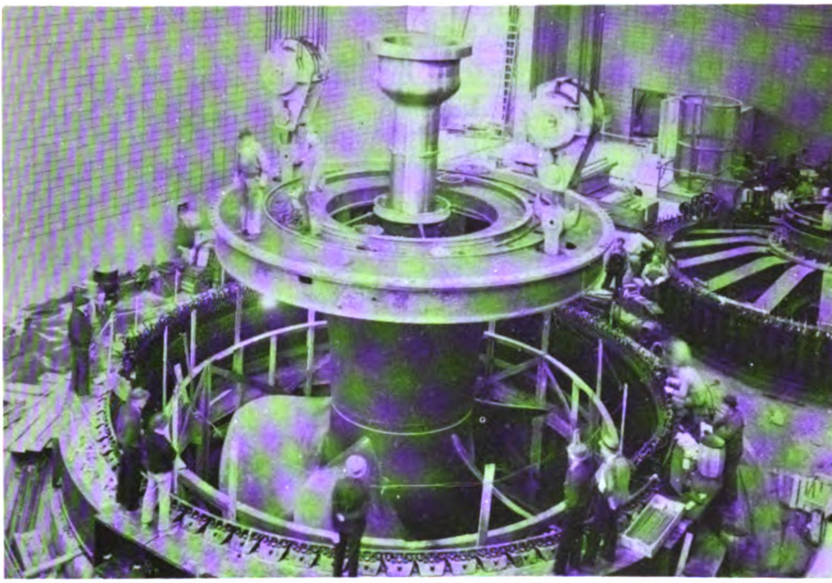


FIGURE 180.—*Lowering Kaplan runner in pit—Chickamauga.*

The remainder of the turbine installation consists of installing the walkway, stairways, handrailing, piping, controls, etc. The controls are a minor part when considered as a part of the purchase price, but they are very important and vital to the successful operation of the machine. They consist of lubricating oil controls, lubricating water controls, temperature controls, and overspeed controls. These devices are installed in their respective locations and are operated manually to check that they operate properly.

Shaft connection

The generator contract usually specifies that the shaft connection between the lower end of the generator shaft and the upper end of the turbine shaft shall be made by the generator manufacturer. It also usually specifies that the generator manufacturer shall make a rotation check of the entire rotating parts and that the shaft throwout at the turbine guide bearing as revealed by the check shall not exceed an amount which is determined by the following formula: $D=\frac{L}{R}\times.00075$ inch. In this formula, D=diameter of throwout circle in thousandths of an inch, L=length of shaft from face of generator thrust bearing to top of turbine bearing in feet, and R=radius of thrust bearing runner plate in feet.

In making the shaft coupling TVA's construction specification states that the coupling bolts shall be prestressed a minimum of 25 percent above any normal operating stress to which these bolts might be subjected. This results in stretching these bolts some 6 to 10 thousandths of an inch.

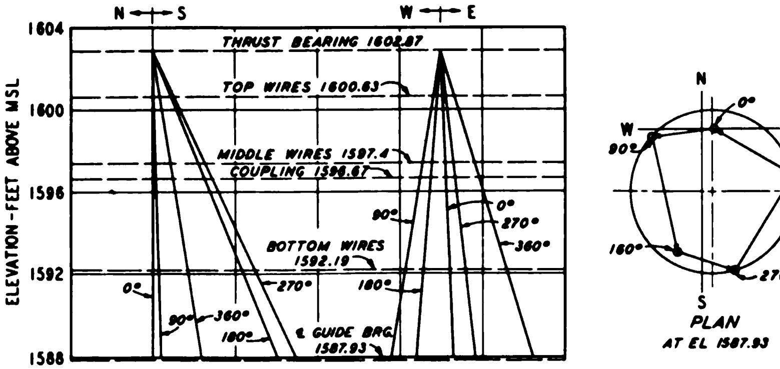


FIGURE 181.—*Rotation check—Wilbur unit 4.*

Rotation check

TVA's construction specification also gives the procedure which shall be used in making the rotation check. Four heavy plumb bobs suspended in oil and supported by piano wire are placed at 90 degrees around the shaft. The length of the wires extend over the maximum possible length of both shafts. From these wires the entire shaft is set vertical to 0.005 inch or less. After the rotation check is completed, the center of rotation at the turbine guide bearing is set central in the bearing, and the generator guide bearings are set central around the guide surface. This procedure eliminates any excessive side thrust upon either the generator or turbine guide bearings which might occur otherwise. Graphical results of a typical rotation check of Wilbur unit 4 are shown in figure 181. Figure 38 in chapter 2 shows the results of Guntersville unit 1 shaft rotation check.

TESTS

Efficiency

To date TVA has completed actual efficiency tests only on the two 66,000-horsepower turbines installed at the Norris plant. These tests were made by the Gibson method, and the results indicated that for both units the actual efficiencies were from 2.1 to 3.9 percent above contract guarantees.

The acceptance tests[1] to determine the efficiencies of the two turbines were conducted during the period of October 20–25, 1937. The tests were made according to the Gibson method[2] for determining the efficiency of hydraulic turbines. Engineers employed by Norman R. Gibson, consulting engineer, with the aid of some personnel recruited from TVA's construction and operating organizations, conducted the tests. A representative of the Newport News Shipbuilding & Dry Dock Co., the turbine manufacturer, and representatives of TVA observed the tests. The results are summarized in table 4.

A detailed discussion of the acceptance test is given in appendix A.

[1] Gibson, Norman R., "Efficiency Test by Gibson Method, Units Nos. 1 and 2, October 20–25, 1937." December 30, 1937.
[2] Gibson, Norman R., "Gibson Method for Field Testing of Hydraulic Turbines, Mechanical Engineering," volume 52 (1930), page 374.

TABLE 4.—*Summary of Norris turbine acceptance test results*

Unit No.	Net head (feet)	Turbine efficiency at 50,000 horsepower (percent)		Turbine efficiency at 75,000 horsepower (percent)	
		Guaranteed	Actual	Guaranteed	Actual
1	180	91.0	93.1	86.0	88.9
2	180	91.0	93.3	86.0	89.9

Unit No.	Net head (feet)	Maximum turbine efficiency occurs at—			Maximum capacity occurs at—		
		Generator (kilowatts)	Turbine (horsepower)	Discharge (cfs)	Generator (kilowatts)	Turbine (horsepower)	Discharge (cfs)
1	180	45,400	62,000	3,259	57,400	78,300	4,560
2	180	42,400-45,000	58,000-62,000	3,045-3,255	57,400	78,300	4,562

Provisions have been made so that efficiency tests can be made on tributary plants where conditions are favorable for such tests. These provisions take the form of piezometer connections which usually are made approximately 100 feet apart to a straight section of the intake pipe, with the lower set of taps being about 5 to 20 feet upstream from the turbine intake.

In the case of the main-river plants, it is not planned to run efficiency tests because of the cost and relative difficulty involved in such measurements, and to the somewhat questionable results which would be obtained due to the error involved in determining the water flow because of the short water passages. For these units, the efficiencies are determined by model tests conducted in a laboratory. The Moody formula is used for converting the model performances into the actual performances of the prototype. The usual practice is to apply the correction computed for the peak of the efficiency curve to the remaining portion of the curve. By referring to figure 182 it will be seen that the efficiency curves of the

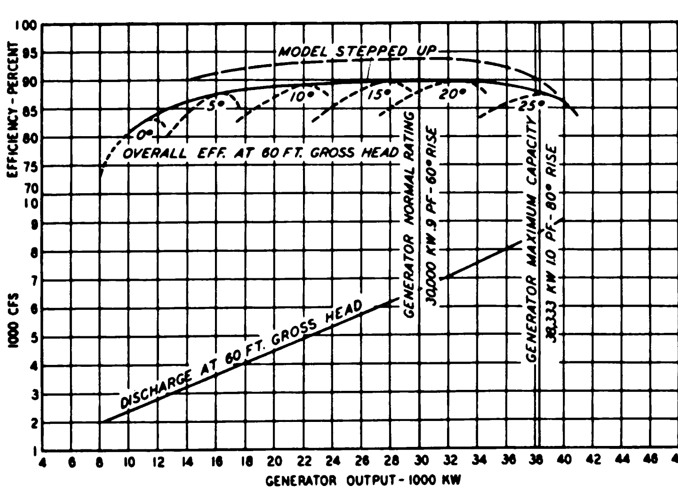


FIGURE 182.—*Overall efficiency and discharge curve of typical Kaplan propeller unit.*

model and the prototype are essentially parallel, which bears out this assumption. Note the flat curve with consistently high efficiencies over a wide range of load. This, of course, is characteristic of adjustable blade turbines, such as are installed in most of the main-river plants.

Efficiency tests for both pump and turbine operation were made on the Hiwassee pump-turbine unit in April 1957. Prior to the test both the Gibson method and the Allen salt velocity method were considered for determining the flow through the unit. The salt velocity method was chosen because it was believed that it would give more reliable results for operation of the unit in the pumping direction.

The principle of the salt velocity method is to inject a salt solution into the penstock and measure electrically the time required for the solution to travel between two points a measured distance apart in the penstock. From this time the average velocity and flow are determined. The power output, headwater and tailwater elevations, gate opening, and penstock head loss are determined similarly to the methods used to determine these quantities in an index test except that steps are taken to provide better accuracy where possible.

Plates 8, 9, 10, and 11 (pages 354–361) show the arrangement and details of the test equipment. For the turbine test the salt solution was injected from the pressure tank on top of the dam through the pop valve station located near the penstock entrance. For the pump test the pressure tank was located near the actuator cabinet and the salt solution injected through the pop valve station in the inlet pipe near the spiral case. The time for the salt solution to travel between the two electrode stations was used to determine the flow. A description of the pump-turbine unit is given in chapter 2, "The Projects."

While final test calculations have not been completed, certain conclusions can be drawn from the preliminary test results. The test of the unit operating as a turbine was successful and the unit met or exceeded the contract guarantee for efficiency and capacity at the head tested. The test of the unit operating as a pump was not successful because of erroneous salt velocity readings. It is believed that the faulty salt velocity measurements were caused by spiral flow conditions present in the pump discharge which continued into the region where the measurements were being taken. The only sure method of improving the salt velocity readings would have been to locate the salt velocity measuring section far enough upstream of the pump discharge to get out of the spiral flow region. This was impossible at Hiwassee because of the short penstock. It is believed that the test made in the pumping direction will be sufficiently accurate to be used for operating data although it cannot be used to check the manufacturer's guarantees.

Capacity

On all plants, capacity tests were made to determine the actual output of the turbine at various heads. If actual efficiency tests have been made on the generators prior to the capacity test, then the actual generator efficiencies are used in computing the turbine output. If the tests have not been made on the generators, then

the manufacturer's guaranteed efficiencies are used for all computations.

Index

Index tests are made on all generating units installed by TVA. While actual efficiency is not determined by these tests they do serve the purpose of determining the relative performance of each turbine at different heads, loads, and gate openings. The peak efficiency is usually computed from the computed generator efficiency, measured penstock and draft tube losses, and the peak efficiency of a homologous model turbine stepped up by the Moody formula. Relative efficiencies, based on this peak efficiency, are determined for various gate openings and blade tilts by measuring the generator output, the headwater and tailwater elevations, the penstock and draft tube losses, and the Winter-Kennedy piezometer differential pressure.

On tributary plants, the index tests serve three major purposes:

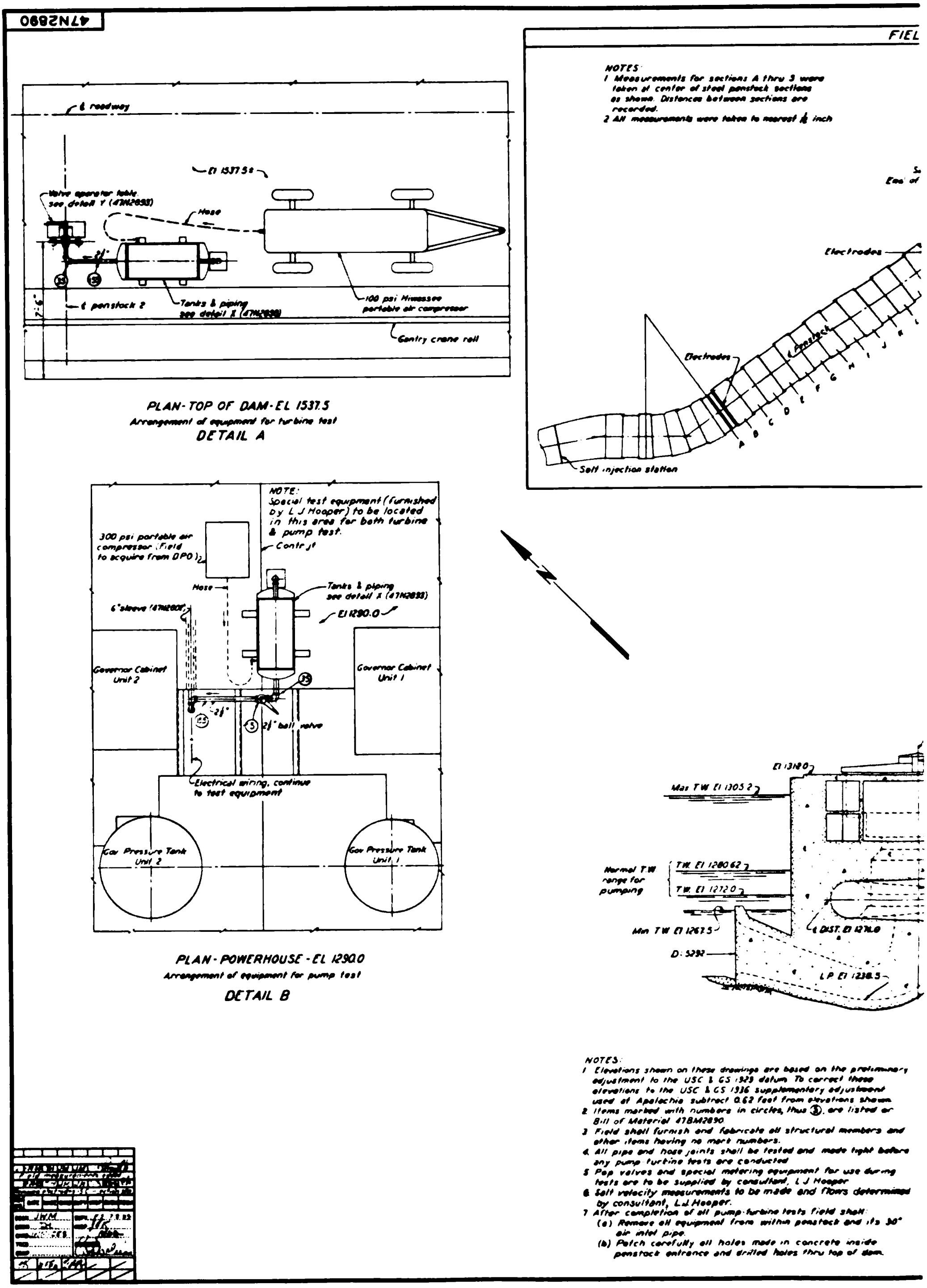
1. To check the turbine performance against the manufacturer's guarantees.
2. To obtain data for construction of operating characteristic curves.
3. To obtain a calibration for the turbine flowmeter.

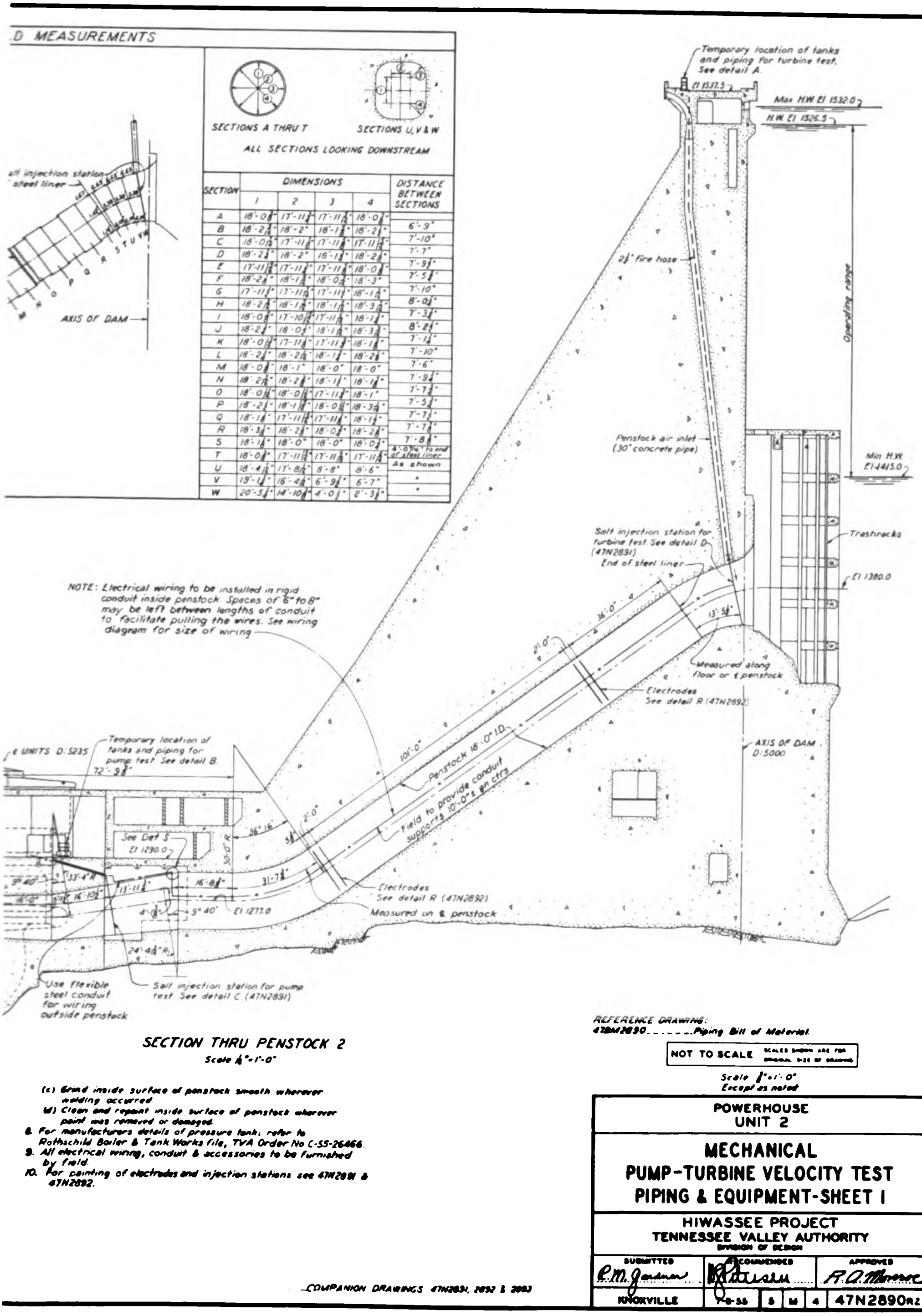
Based on the assumption that the combined efficiencies of the turbine, the generator, and the water passages including the penstocks would give an overall efficiency of 88.5 percent under a gross head of 115 feet, the curves in figure 183 (page 362) were constructed. These curves, which are for a Francis runner, show the relative efficiency of this turbine over the extreme head variations from 145 feet down to 55 feet.

The index tests on the main-river plants serve four major purposes, three being the same as those on the tributary plants and the fourth being the shaping of the cams which adjust the tilts of the runner blades to the most efficient blade angle for any given gate opening. Figure 182 shows the over-all efficiency, output, and corresponding discharges of recent tests on a Kaplan runner. This curve is based on the assumption that the combined efficiencies of the turbine (from model test), the generator manufacturer's guarantee, and the water passages would give a maximum overall efficiency of 90 percent under a gross head of 60 feet. The individual blade angle curves at each 5 degrees (shown dotted on the chart) were obtained by blocking the runner blades in a fixed position and varying the gate openings to obtain readings over the peak efficiency range of each individual blade setting. The peaks of these individual curves represent the maximum overall efficiency which can be obtained with that particular blade setting and the correspondingly correct gate opening. The envelope curve, drawn through the peaks of each of these individual curves, represents the best overall gate blade relation. Therefore, the cams which control the blade angles are shaped to give this relation. After the cams have been shaped, a new set of data is obtained to check the shape of the cam as altered.

All the units TVA has tested to date have exceeded the manufacturer's horsepower guarantees.

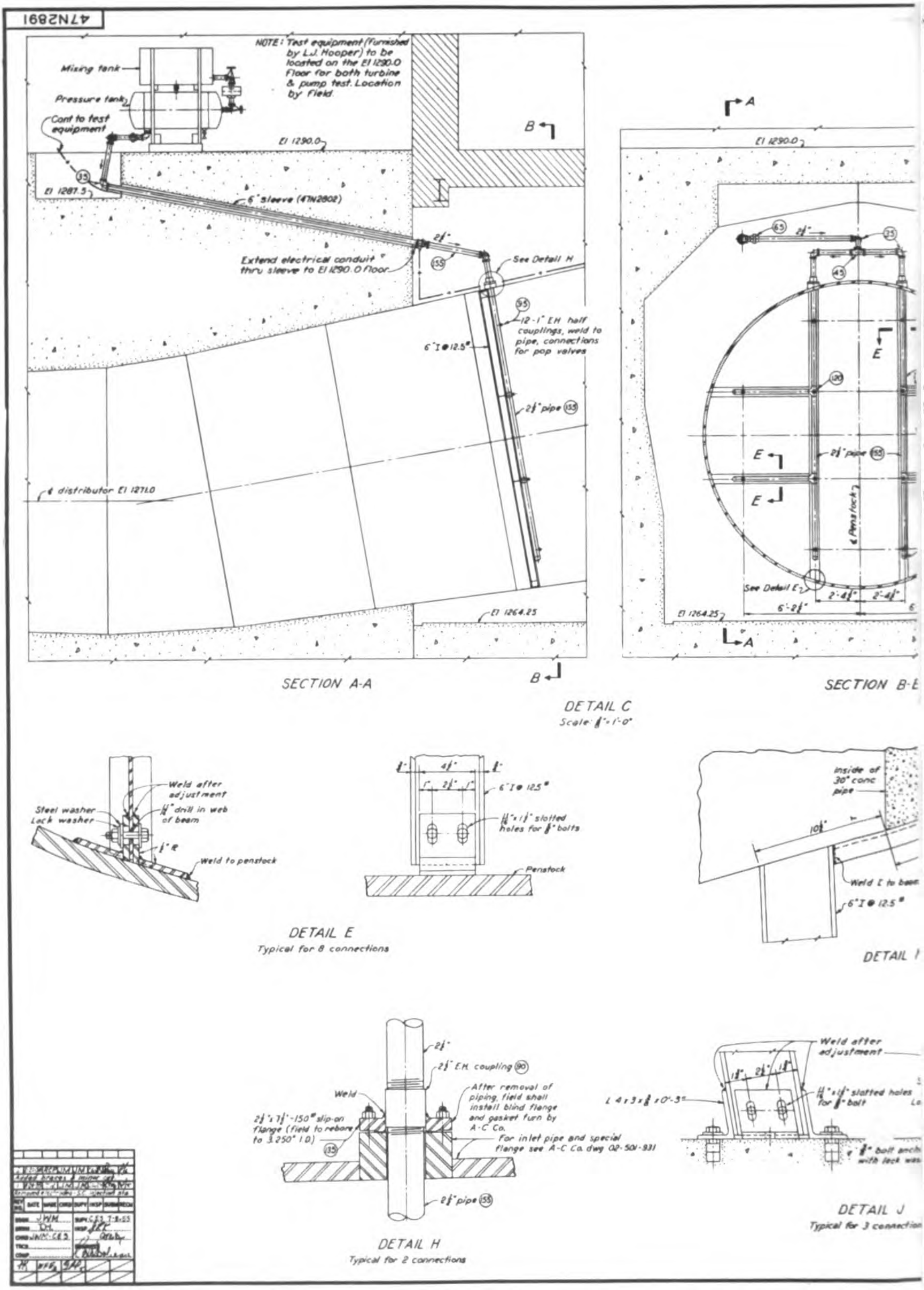
Complete index test reports on both Kaplan and Francis type units are included in appendix A.


47N2890
FIEL
NOTES
1 Measurements for sections A thru 3 were taken at center of steel penstock sections as shown. Distances between sections are recorded.
2 All measurements were taken to nearest 1/8 inch
Electrodes
Electrodes
Penstock
Salt injection station
℄ roadway
El 1537.5±
Valve operator table see detail Y (47N2893)
Hose
℄ penstock 2
Tanks & piping see detail X (47N2893)
100 psi Hinessee portable air compressor
Gantry crane rail
PLAN-TOP OF DAM-EL 1537.5
Arrangement of equipment for turbine test
DETAIL A
NOTE:
Special test equipment (furnished by L J Hooper) to be located in this area for both turbine & pump test.
Contr. jt
300 psi portable air compressor (Field to acquire from DPO)
Hose
Tanks & piping see detail X (47N2893)
El 1290.0
Governor Cabinet Unit 2
Governor Cabinet Unit 1
2½" ball valve
Electrical wiring, continue to test equipment
Gov Pressure Tank Unit 2
Gov Pressure Tank Unit 1
PLAN-POWERHOUSE-EL 1290.0
Arrangement of equipment for pump test
DETAIL B
El 1318.0
Max TW El 1305.2
Normal TW range for pumping
TW El 1280.62
TW El 1272.0
Min TW El 1267.5
℄ DIST. El 1276.0
LP El 1238.5
NOTES:
1 Elevations shown on these drawings are based on the preliminary adjustment to the USC & GS 1929 datum. To correct these elevations to the USC & GS 1936 supplementary adjustment used at Apalachia subtract 0.62 feet from elevations shown.
2 Items marked with numbers in circles, thus 5, are listed on Bill of Material 47BM2890.
3 Field shall furnish and fabricate all structural members and other items having no mark numbers.
4 All pipe and hose joints shall be tested and made tight before any pump-turbine tests are conducted.
5 Pop valves and special metering equipment for use during tests are to be supplied by consultant, L J Hooper.
6 Salt velocity measurements to be made and flows determined by consultant, L J Hooper.
7 After completion of all pump-turbine tests field shall:
(a) Remove all equipment from within penstock and its 30" air inlet pipe.
(b) Patch carefully all holes made in concrete inside penstock entrance and drilled holes thru top of dam.

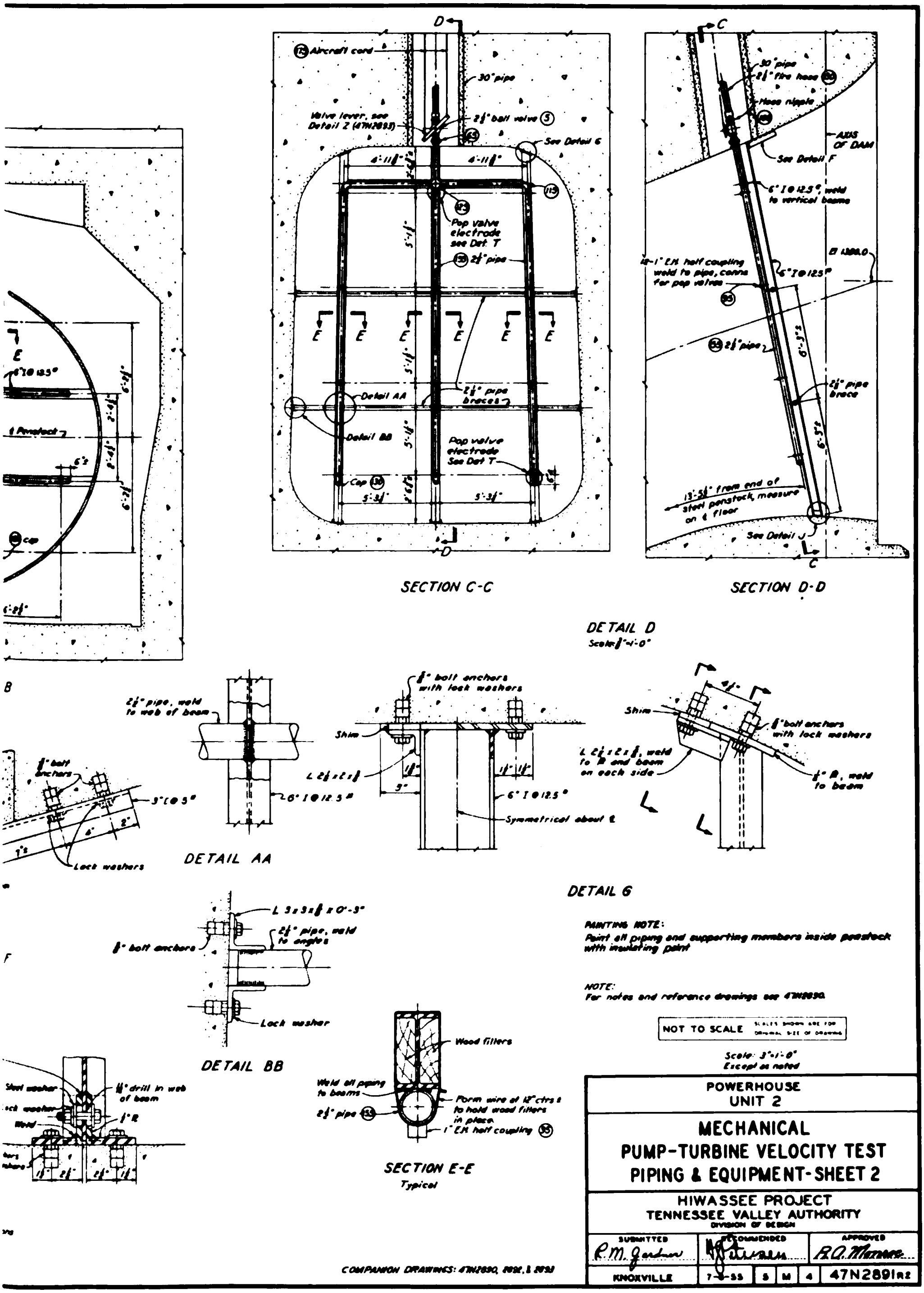


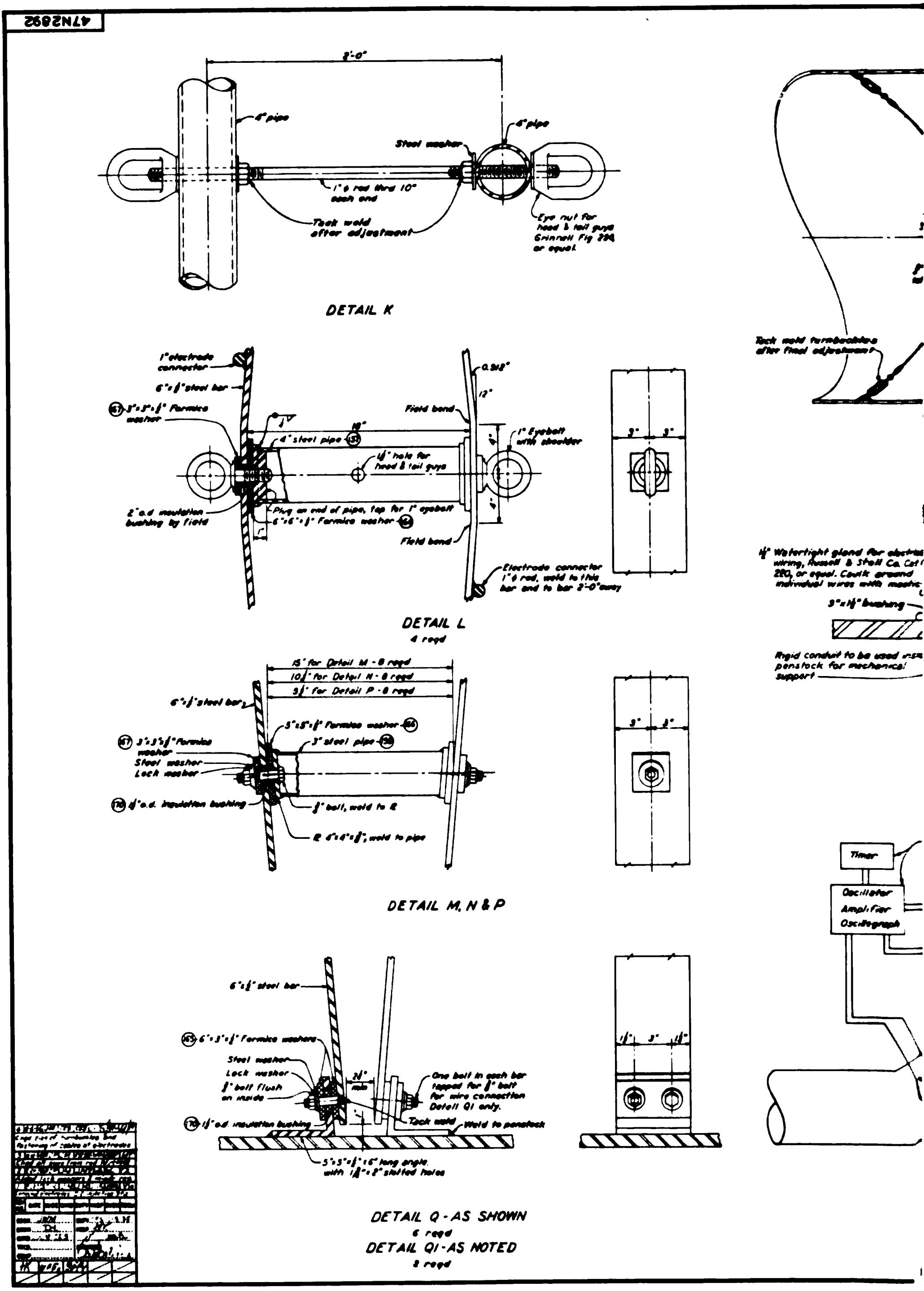
SECTION	DIMENSIONS 1	2	3	4	DISTANCE BETWEEN SECTIONS
A	18'-0[illegible]"	17'-11[illegible]"	17'-11[illegible]"	18'-0[illegible]"	
B	18'-2[illegible]"	18'-2"	18'-1[illegible]"	18'-2[illegible]"	6'-9"
C	18'-0[illegible]"	17'-11[illegible]"	17'-11[illegible]"	17'-11[illegible]"	7'-10"
D	18'-2[illegible]"	18'-2"	18'-1[illegible]"	18'-2[illegible]"	7'-7"
E	17'-11[illegible]"	17'-11[illegible]"	17'-11[illegible]"	18'-0[illegible]"	7'-9[illegible]"
F	18'-2[illegible]"	18'-1[illegible]"	18'-0[illegible]"	18'-3"	7'-5[illegible]"
G	17'-11[illegible]"	17'-11[illegible]"	17'-11[illegible]"	18'-1[illegible]"	7'-10"
H	18'-2[illegible]"	18'-1[illegible]"	18'-1[illegible]"	18'-3[illegible]"	8'-0[illegible]"
I	18'-0[illegible]"	17'-10[illegible]"	17'-11[illegible]"	18'-1[illegible]"	7'-3[illegible]"
J	18'-2[illegible]"	18'-0[illegible]"	18'-1[illegible]"	18'-3[illegible]"	8'-2[illegible]"
K	18'-0[illegible]"	17'-11[illegible]"	17'-11[illegible]"	18'-1[illegible]"	7'-1[illegible]"
L	18'-2[illegible]"	18'-2[illegible]"	18'-1[illegible]"	18'-2[illegible]"	7'-10"
M	18'-0[illegible]"	18'-1"	18'-0"	18'-0"	7'-6"
N	18'-2[illegible]"	18'-2[illegible]"	18'-1[illegible]"	18'-1[illegible]"	7'-9[illegible]"
O	18'-0[illegible]"	18'-0[illegible]"	17'-11[illegible]"	18'-1"	7'-7[illegible]"
P	18'-2[illegible]"	18'-1[illegible]"	18'-0[illegible]"	18'-3[illegible]"	7'-5[illegible]"
Q	18'-1[illegible]"	17'-11[illegible]"	17'-11[illegible]"	18'-1[illegible]"	7'-7[illegible]"
R	18'-3[illegible]"	18'-2[illegible]"	18'-0[illegible]"	18'-2[illegible]"	7'-7[illegible]"
S	18'-1[illegible]"	18'-0"	18'-0"	18'-0[illegible]"	7'-8[illegible]"
T	18'-0[illegible]"	17'-11[illegible]"	17'-11[illegible]"	17'-11[illegible]"	4'-0[illegible]" to end of steel liner
U	18'-4[illegible]"	17'-8[illegible]"	8'-8"	8'-6"	As shown
V	19'-1[illegible]"	16'-4[illegible]"	6'-9[illegible]"	6'-7"	"
W	20'-5[illegible]"	14'-10[illegible]"	4'-0[illegible]"	2'-3[illegible]"	"

PLATE 8

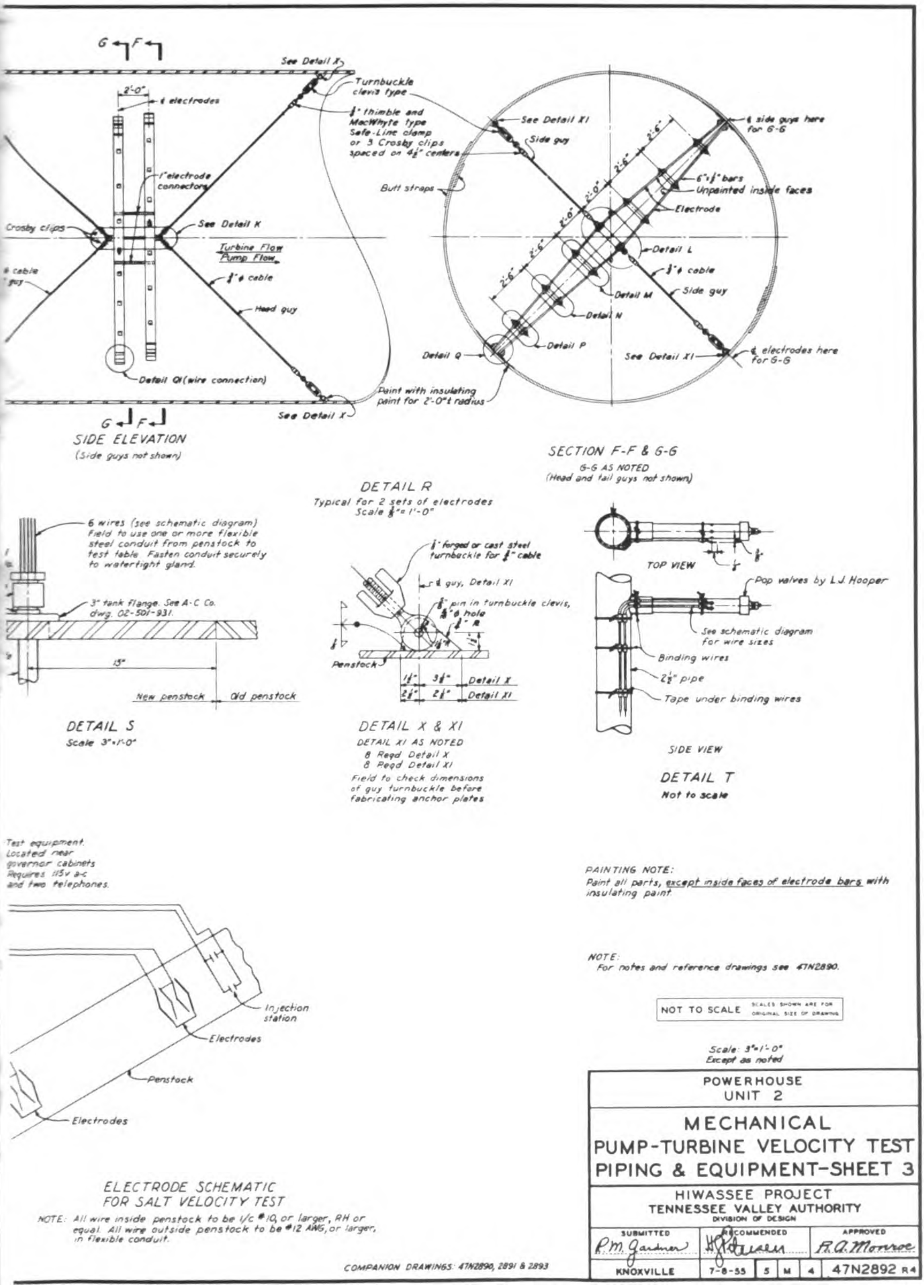


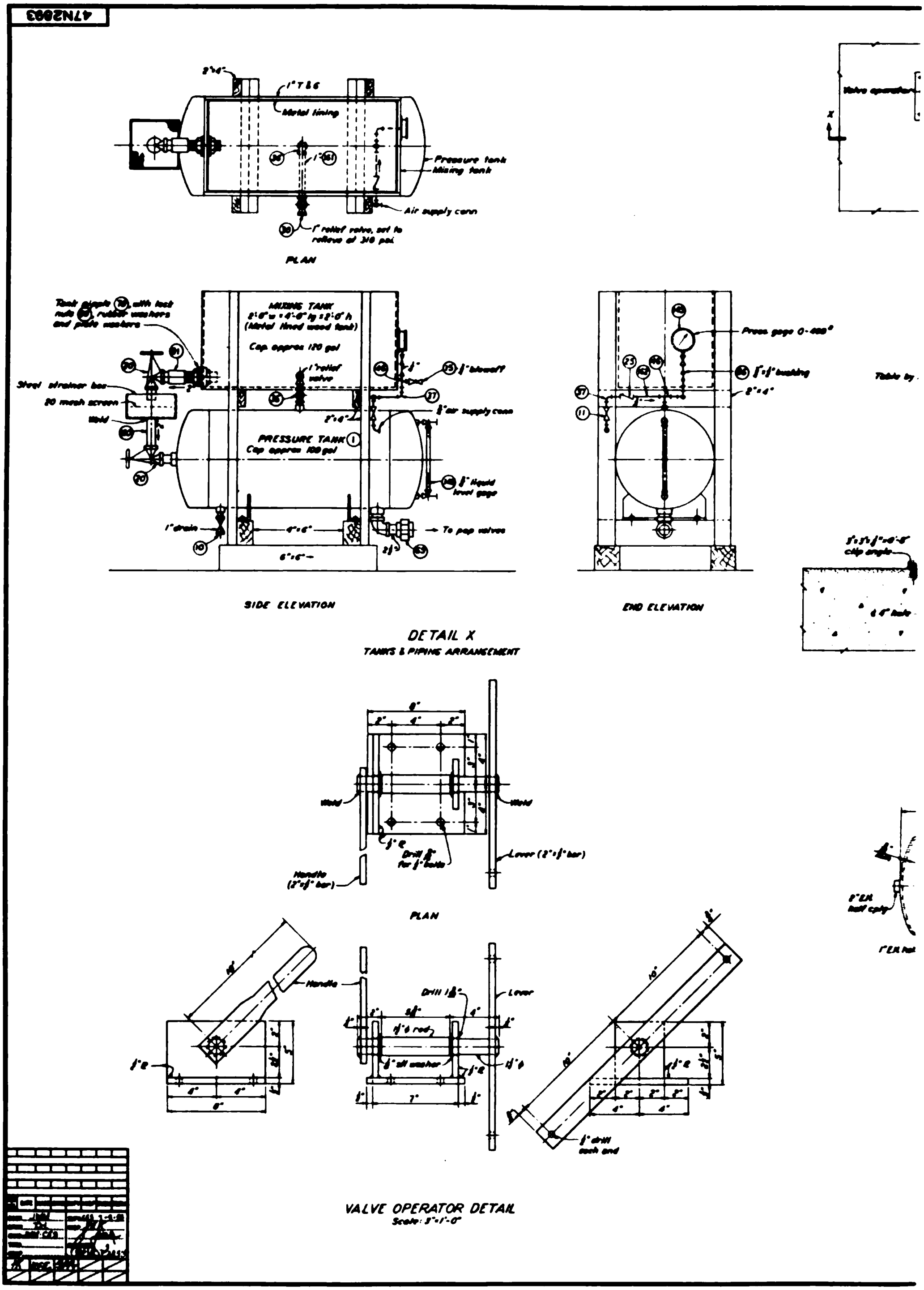
47N2891
NOTE: Test equipment (Furnished by L.J. Hooper) to be located on the El 1290.0 Floor for both turbine & pump test. Location by Field.
Mixing tank
Pressure tank
Cont to test equipment
El 1290.0
El 1287.5
6" Sleeve (47N2802)
Extend electrical conduit thru sleeve to El 1290.0 Floor
See Detail H
12-1" EH half couplings, weld to pipe, connections for pop valves
6" I @ 12.5#
2½" pipe
℄ distributor El 1271.0
El 1264.25
SECTION A-A
SECTION B-B
℄ Penstock
See Detail E
DETAIL C
Scale: ¾"=1'-0"
6" I @ 12.5#
Penstock
Weld after adjustment
Steel washer
Lock washer
drill in web of beam
Weld to penstock
DETAIL E
Typical for 8 connections
Inside of 30" conc pipe
Weld to beam
DETAIL H
Typical for 2 connections
2½" E.H. coupling
After removal of piping, field shall install blind flange and gasket furn by A-C Co.
For inlet pipe and special flange see A-C Co. dwg 02-501-931
Weld
2½" pipe
DETAIL J
Typical for 3 connections


SECTION C-C
SECTION D-D
DETAIL D
DETAIL AA
DETAIL 6
DETAIL BB
SECTION E-E
Typical
PAINTING NOTE:
Paint all piping and supporting members inside penstock with insulating paint
NOTE:
For notes and reference drawings see 47N2890.
NOT TO SCALE
Scale: 3"=1'-0"
Except as noted
POWERHOUSE
UNIT 2
MECHANICAL
PUMP-TURBINE VELOCITY TEST
PIPING & EQUIPMENT-SHEET 2
HIWASSEE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
47N2891R2
COMPANION DRAWINGS: 47N2890, 2892, & 2893



DETAIL K
DETAIL L
4 reqd
DETAIL M, N & P
DETAIL Q - AS SHOWN
6 reqd
DETAIL Q1 - AS NOTED
4" pipe
Steel washer
Tack weld after adjustment
6"x1/2" steel bar
4" steel pipe
Field bend
Electrode connector
3" steel pipe
Timer
Oscillator
Amplifier
Oscillograph


See Detail X
Turnbuckle clevis type
2'-0"
℄ electrodes
⅜" thimble and MacWhyte type Safe-Line clamp or 3 Crosby clips spaced on 4½" centers
1" electrode connectors
Crosby clips
See Detail K
Turbine Flow
Pump Flow
⅜" ⌀ cable
Head guy
Detail Q1 (wire connection)
Paint with insulating paint for 2'-0" ℄ radius
SIDE ELEVATION
(Side guys not shown)
See Detail XI
Side guy
Butt straps
℄ side guys here for G-G
6"x⅝" bars
Unpainted inside faces
Electrode
Detail L
⅜" ⌀ cable
Detail M
Detail N
Detail P
Detail Q
See Detail XI
℄ electrodes here for G-G
SECTION F-F & G-G
G-G AS NOTED
(Head and tail guys not shown)
DETAIL R
Typical for 2 sets of electrodes
Scale ⅜" = 1'-0"
6 wires (see schematic diagram) Field to use one or more flexible steel conduit from penstock to test table. Fasten conduit securely to watertight gland.
3" tank flange. See A-C Co. dwg. 02-501-931.
15"
New penstock
Old penstock
DETAIL S
Scale 3"=1'-0"
⅝" forged or cast steel turnbuckle for ⅜" cable
℄ guy, Detail XI
⅝" pin in turnbuckle clevis, 11/16" ⌀ hole
Penstock
Detail X
Detail XI
DETAIL X & XI
DETAIL XI AS NOTED
8 Reqd Detail X
8 Reqd Detail XI
Field to check dimensions of guy turnbuckle before fabricating anchor plates
TOP VIEW
Pop valves by L.J. Hooper
See schematic diagram for wire sizes
Binding wires
2½" pipe
Tape under binding wires
SIDE VIEW
DETAIL T
Not to scale
Test equipment. Located near governor cabinets. Requires 115v a-c and two telephones.
Injection station
Electrodes
Penstock
Electrodes
ELECTRODE SCHEMATIC FOR SALT VELOCITY TEST
NOTE: All wire inside penstock to be 1/c #10, or larger, RH or equal. All wire outside penstock to be #12 AWG, or larger, in flexible conduit.
PAINTING NOTE: Paint all parts, except inside faces of electrode bars with insulating paint.
NOTE: For notes and reference drawings see 47N2890.
NOT TO SCALE
SCALES SHOWN ARE FOR ORIGINAL SIZE OF DRAWING
Scale: 3"=1'-0"
Except as noted
COMPANION DRAWINGS: 47N2890, 2891 & 2893
POWERHOUSE
UNIT 2
MECHANICAL
PUMP-TURBINE VELOCITY TEST
PIPING & EQUIPMENT-SHEET 3
HIWASSEE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
7-8-55
47N2892 R4


47N2883
Metal lining
Pressure tank
Mixing tank
Air supply conn
PLAN
MIXING TANK
(Metal lined wood tank)
Cap approx 120 gal
Steel strainer box
20 mesh screen
Weld
PRESSURE TANK
Cap approx 100 gal
To pop valves
SIDE ELEVATION
END ELEVATION
DETAIL X
TANKS & PIPING ARRANGEMENT
Weld
Lever
Handle
PLAN
Lever
Handle
VALVE OPERATOR DETAIL

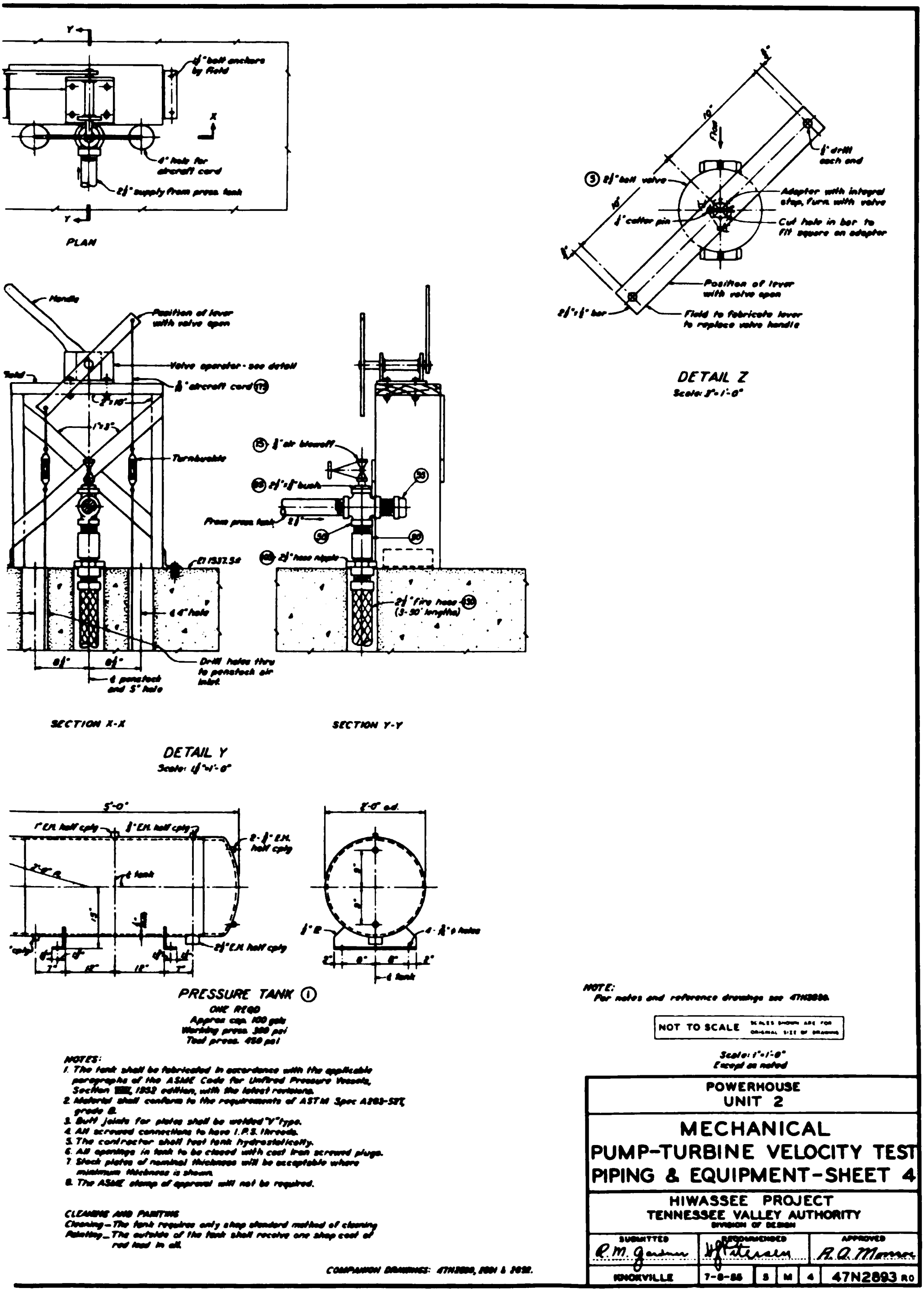
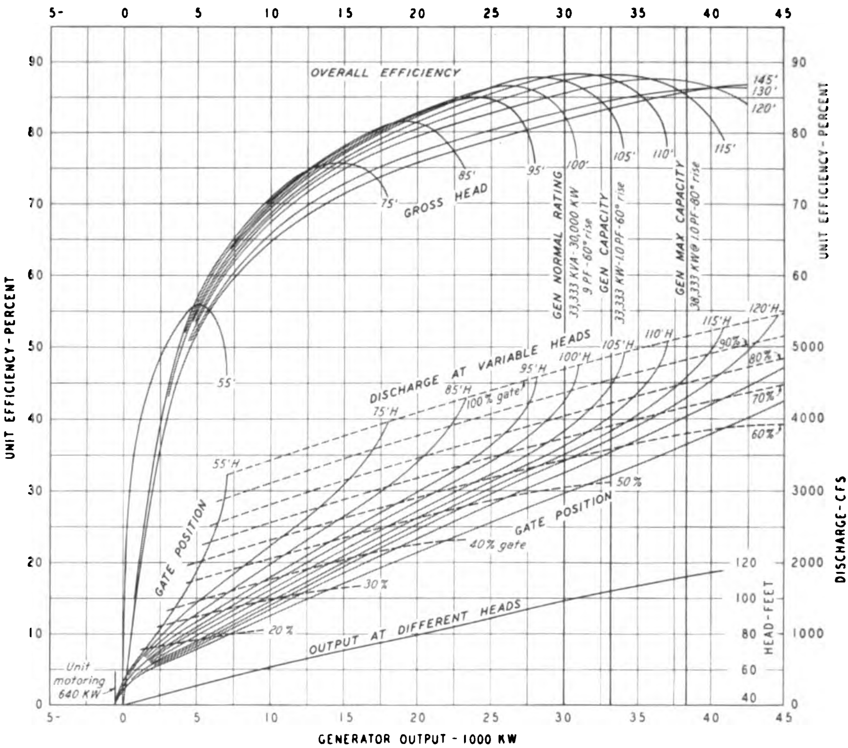

PLAN
2½" bolt anchors by field
4" hole for aircraft cord
2½" supply from press. tank
Handle
Position of lever with valve open
Valve operator - see detail
⅛" aircraft cord
Turnbuckle
4" hole
Drill holes thru to penstock air inlet
℄ penstock and 5" hole
SECTION X-X
½" air blowoff
2½"x⅞" bush
From press. tank
2½" hose nipple
2½" fire hose (3-50' lengths)
SECTION Y-Y
DETAIL Y
2½" ball valve
½" cotter pin
Adaptor with integral stop, furn. with valve
Cut hole in bar to fit square on adaptor
Position of lever with valve open
Field to fabricate lever to replace valve handle
DETAIL Z
5'-0"
¾" E.H. half cplg
2½" E.H. half cplg
℄ tank
PRESSURE TANK ①
ONE REQD
Approx cap. 100 gals
Working press. 300 psi
Test press. 450 psi
NOTES:
1. The tank shall be fabricated in accordance with the applicable paragraphs of the ASME Code for Unfired Pressure Vessels, Section , 1952 edition, with the latest revisions.
2. Material shall conform to the requirements of ASTM Spec A283-52T, grade B.
3. Butt joints for plates shall be welded "V" type.
4. All screwed connections to have I.P.S. threads.
5. The contractor shall test tank hydrostatically.
6. All openings in tank to be closed with cast iron screwed plugs.
7. Stock plates of nominal thickness will be acceptable where minimum thickness is shown.
8. The ASME stamp of approval will not be required.
CLEANING AND PAINTING
Cleaning—The tank requires only shop standard method of cleaning
Painting—The outside of the tank shall receive one shop coat of red lead in oil.
COMPANION DRAWINGS:
NOTE:
For notes and reference drawings see
NOT TO SCALE
Scale: 1"=1'-0"
Except as noted
POWERHOUSE
UNIT 2
MECHANICAL
PUMP-TURBINE VELOCITY TEST
PIPING & EQUIPMENT-SHEET 4
HIWASSEE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
7-8-55
47N2893 R0

PLATE 11



NOTES:

The following cavitation guarantees should be observed during the first year of operation in order not to void the guarantees.

HEAD-FEET	OUTPUT HORSEPOWER MINIMUM Not more than 800 hours	OUTPUT HORSEPOWER MAXIMUM Do not exceed for more than 50 hrs altogether
146	20,000	50,000
125	20,000	50,000
110	20,000	49,100
100	20,000	41,500
75	20,000	23,000
55	8,500	9,000

Based on experience curves furnished by S Morgan Smith Co. revised from data obtained from index test on unit 1. Data should be revised to include other field tests of turbine & generators.

TURBINES RATED:
41,500 HP-100' head-94.7 RPM - manufactured by S. Morgan Smith Co., York, Pa.

GENERATOR RATED:
33,333 KVA-3 phase-60 cycles-13,800 volts-.9 power factor-60° rise 94.7 rpm, manufactured by General Electric Co., Schenectady, N.Y.

FIGURE 183.—*Operating characteristic curves for typical Francis unit.*

Servomotor

In addition to the efficiency and index tests discussed above, the servomotors are tested for actual operating pressures required. This is accomplished by installing pressure gages in the oil line on both sides of the pistons. The turbine wicket gates are then slowly opened and closed during which time the pressure gauges are read at each 5 percent gate position. In opening or closing the gates, care must be taken to ensure that the movement is continuous and steady, since sudden movement would produce false pressures. On Kaplan runners this same test is made on the servomotor which operates the runner blades.

Model tests

TVA requires the turbine contractor to furnish test data of a homologous model turbine runner for each turbine. These data

include curves of unit horsepower, unit discharge, and efficiency plotted against unit speed; and curves of unit horsepower, unit discharge, and efficiency plotted against sigma for the full range of heads under which the turbine is expected to operate. TVA changes all model performance data to a common basis of a 12-inch diameter runner operating under a net head of 1 foot and replots it in the form of an oak tree curve. Oak tree curves of a typical Francis runner are shown in plate 7, page 262, and of typical Kaplan and fixed blade runners in plates 12 and 13.

In cases where the turbine manufacturer does not already have complete test data of a homologous model, he is required to make a model test. TVA's design division has a representative present during the final stages of these tests to check the test equipment setup and the results of the test.

TURBINE INLET VALVES

TVA has built four plants, Apalachia, Ocoee No. 3, Watauga, and South Holston, where valves were required in the penstock. At each of these plants, tunnels and surge tanks are involved. In general, intake valves are required only in plants similar to these where large amounts of water are involved in watering and unwatering the turbines. In valves of this size and for this type of service, there are two general types of valves manufactured. They are commonly known as the butterfly valve and the Dow disc-arm pivot valve.

In each of the above plants TVA has installed valves of the butterfly type in preference to the Dow type for two reasons: (1) the cost of the butterfly valve is somewhat less than a Dow valve and (2) the valves are to be operated only at full open or closed position and are not expected to operate against flow except in cases of extreme emergency. Figure 184 shows one of the butterfly valves installed at the Apalachia plant.

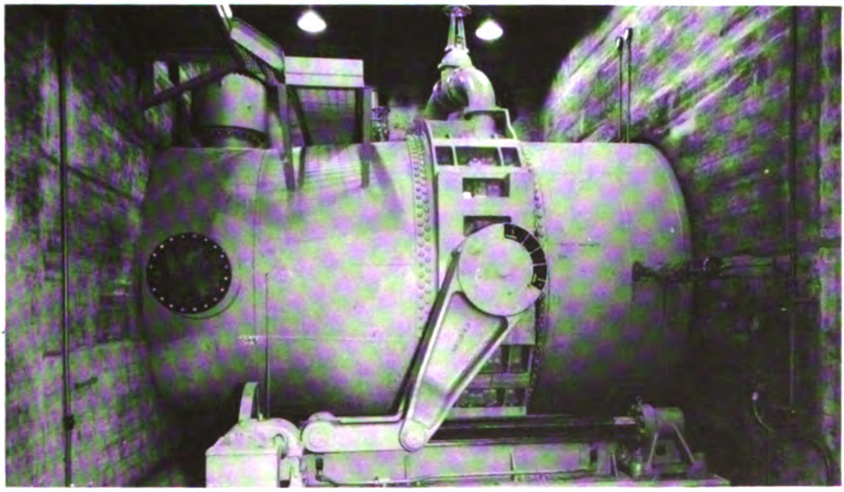
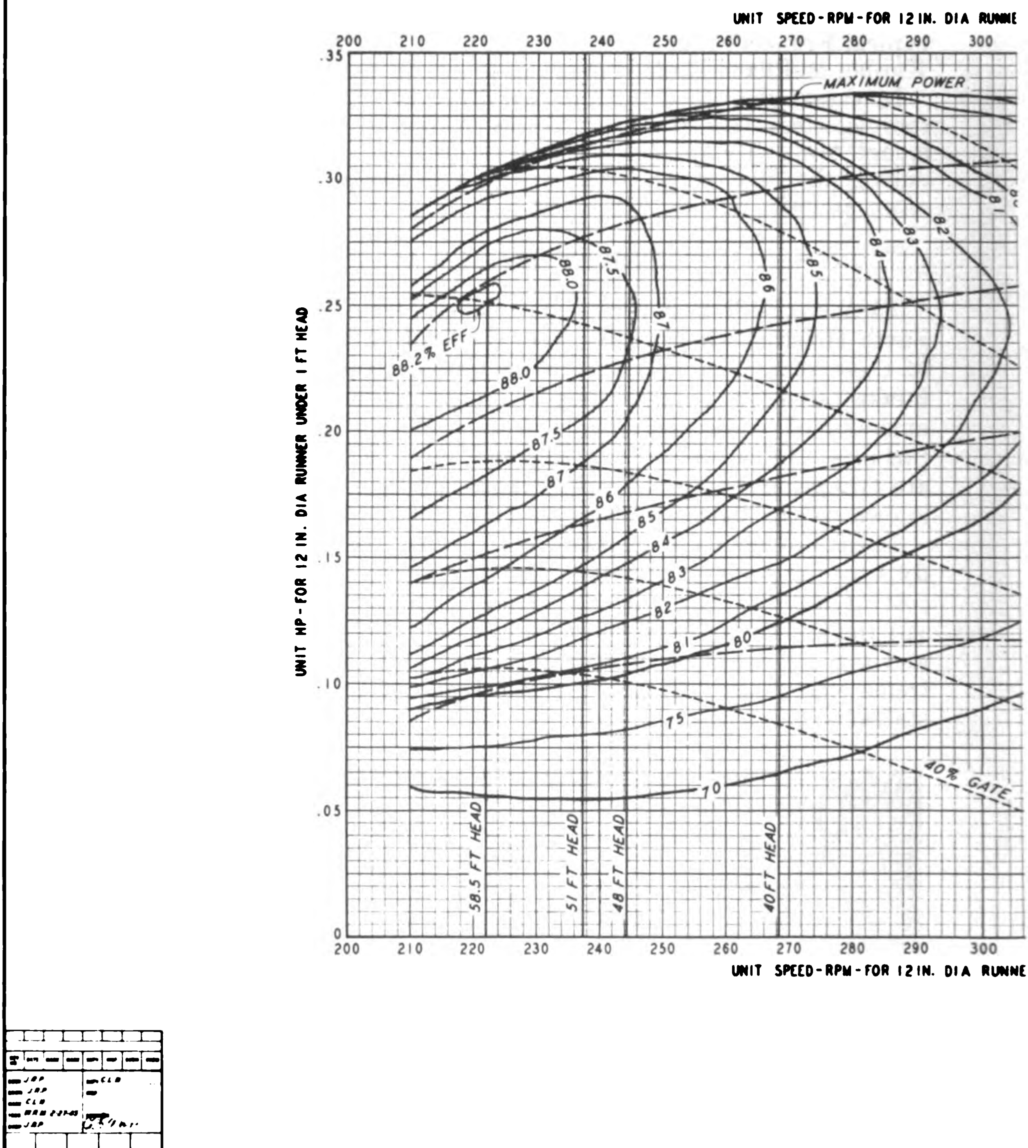
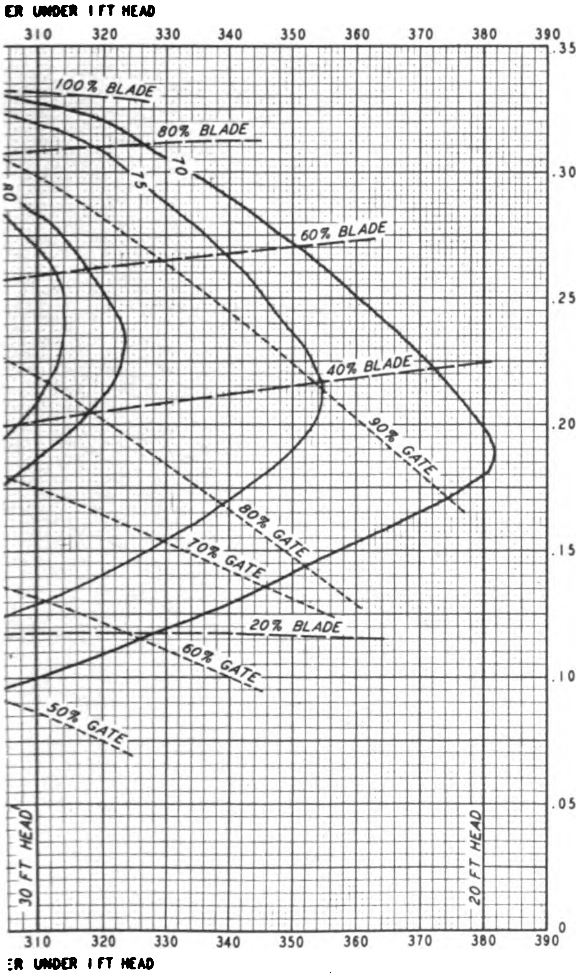


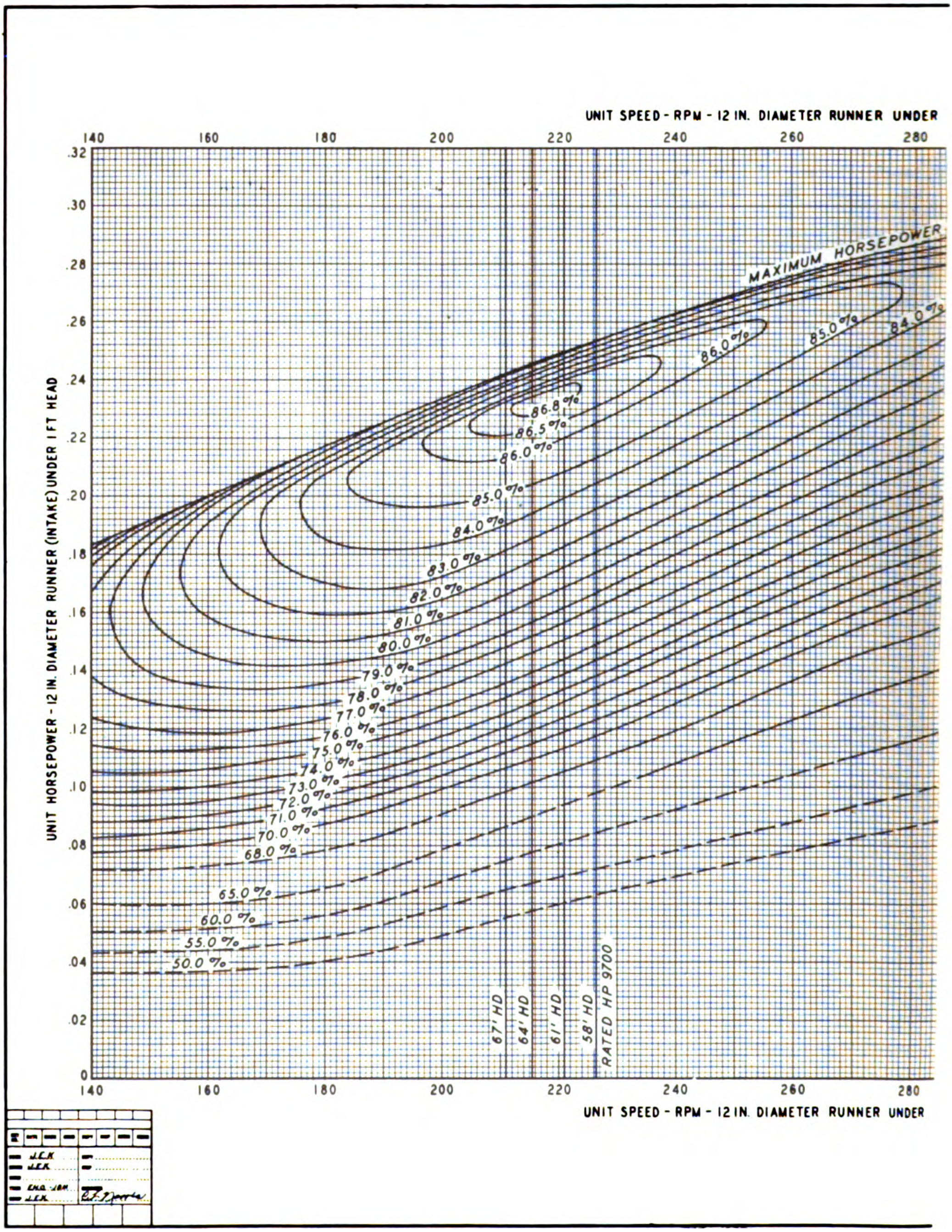
FIGURE 184.—*12-foot-diameter butterfly valve—Apalachia.*

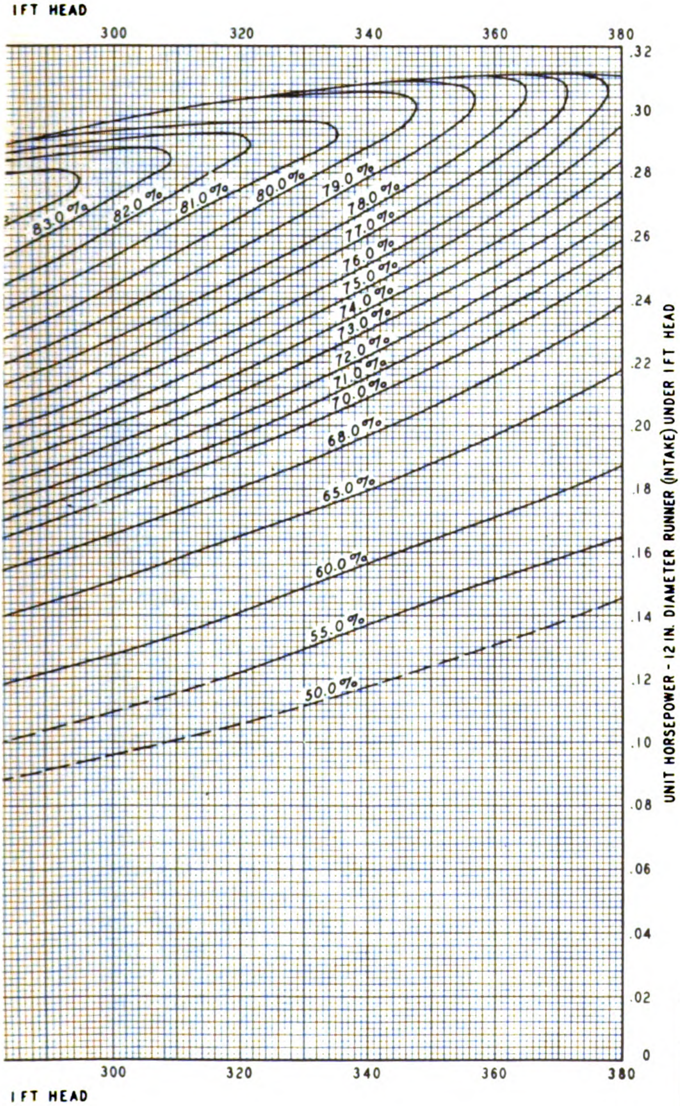

UNIT SPEED-RPM-FOR 12 IN. DIA RUNNE
UNIT HP-FOR 12 IN. DIA RUNNER UNDER 1 FT HEAD
MAXIMUM POWER
88.2% EFF
88.0
87.5
87
86
85
84
83
82
81
80
75
70
40% GATE
58.5 FT HEAD
51 FT HEAD
48 FT HEAD
40 FT HEAD



NOTES:
Based on test No. 3155-2 by Allis-Chalmers Mfg Co, February-March, 1942, 12 1/8 in. Model No. 483-A2 with draft tube, intake, scroll case, and imbedded parts homologous to prototype.
Prototype Rating: 44,000 hp at 48 ft head, 78.3 rpm Diameter - 260 in.

POWERHOUSE					
OAK TREE CURVE OF KAPLAN RUNNER NO. 483-A2 UNDER 1 FT HEAD FOR 12 IN. DIA					
KENTUCKY PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT					
SUBMITTED	RECOMMENDED	APPROVED			
KNOXVILLE	2-27-45	8	M	4	40K903


UNIT SPEED - RPM - 12 IN. DIAMETER RUNNER UNDER
140
160
180
200
220
240
260
280
.32
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
UNIT HORSEPOWER - 12 IN. DIAMETER RUNNER (INTAKE) UNDER 1 FT HEAD
MAXIMUM HORSEPOWER
86.8 %
86.5 %
86.0 %
85.0 %
84.0 %
83.0 %
82.0 %
81.0 %
80.0 %
79.0 %
78.0 %
77.0 %
76.0 %
75.0 %
74.0 %
73.0 %
72.0 %
71.0 %
70.0 %
68.0 %
65.0 %
60.0 %
55.0 %
50.0 %
67' HD
64' HD
61' HD
58' HD
RATED HP 9700
UNIT SPEED - RPM - 12 IN. DIAMETER RUNNER UNDER



NOTES:

Based on model test No. 236 of the James Leffel & Co. model runner conducted December 1939, on 48" fixed blade propeller, type "A" runner.

12" prototype efficiencies computed by application of Moody formula to maximum efficiency irrespective of speed.

$E = 100-(100-e)(\frac{d}{D})^{.25}$

$90.7 = 100-(100-e)(\frac{12}{48})^{.25}$

$e = 86.8\%$

Differential subtracted = 90.7 - 86.8 = 3.9 %

Dashed portion of efficieny curves are approximations.

Prototype rating - 9,700 hp at 180 rpm and 58' head, runner diameter = 115"

POWERHOUSE

OAK TREE CURVES OF FIXED BLADE PROPELLOR TYPE "A" RUNNER UNDER 1' HEAD FOR 12" DIAMETER

WILBUR PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED C. L. Norris | RECOMMENDED | APPROVED R. A. Monroe

KNOXVILLE | 0-7-49 | 58 | M | 4 | 47K900

The disc-arm pivot valve has one probable advantage over the butterfly valve with respect to leakage. The construction of the disc-arm pivot valve is such that a tight closure can be made with less torsional stresses in the downstream half of the disc.

The space requirements for the two valves with the operating mechanism are nearly the same. However, a detailed study should be made of each proposed installation since the butterfly valve requires a greater floor space whereas the disc-arm pivot valve requires greater headroom. The body length of the butterfly valve is approximately one-third less than the body length of the disc-arm pivot valve. Plate 5, page 212, illustrates the general arrangement of the butterfly valves installed in Watauga powerhouse.

SPECIFICATION REQUIREMENTS

Prior to the purchase of the turbines, governors (discussed in next chapter), and inlet valves, TVA prepares a detailed specification covering the following general data and requirements:

A brief description of the plant, giving the plant location, type of turbines, and nearest shipping point.

Detailed description of the penstock or intake, stating the length, size, material, and data concerning the surge tank, if a surge tank is employed.

Complete turbine and generator rating data, including maximum and minimum head, capacity, and operating conditions and requirements.

Type of control, whether remote or manual.

Drawing requirements, material and workmanship, shop inspection, shop erection, shop cleaning and painting, shop marking, and preparation for shipment.

Limiting stresses for all parts and assemblies with material specification for all metals and alloys.

A detailed description of each major part or assembly is given which states the material to be used. Tests are described and the required spare parts are listed. Specifications for typical Francis and Kaplan turbines and turbine inlet valves are included in appendix A.

COST DATA

The "Hydro Generating Equipment—Factual Data" tabulation in appendix A shows the contract price and price per kilowatt of rated capacity of the various turbines and governors installed by TVA. Because of the many variables involved in turbine prices such as type of turbine, size of the unit, head, and prevailing material and labor costs, the TVA gets estimating prices for study purposes from the turbine manufacturers prior to the actual preparation of turbine specifications.

Chapter 4

GOVERNORS FOR HYDRAULIC TURBINES

The electric power produced by TVA is generated at a frequency of 60 cycles and because the energy is used by a large number of consumers for a great variety of purposes, it is of paramount importance that the speed of the system be held within very narrow limits to maintain this frequency. This is accomplished for the hydro units by the use of governors which control the speed of the hydraulic turbines. Figure 185 shows the cabinet housing the governors for units 1 and 2 at the Watts Bar hydro plant.

TVA specifies that each individual machine shall have the desired speed characteristics when operating on an isolated system, that is, not interconnected with other generators. The governors which TVA has purchased are required to start a corrective movement of the gates upon a speed change of 0.06 percent of rated speed. All speed controlling governors will start a corrective movement only *after* there has been a speed change. The interval of time between the actual speed change and the start of the corrective movement by the governor is a measure of the sensitivity of the governor. A jointly sponsored ASME–AIEE Specifications for Governors for Hydraulic Turbines calls for the governor to be sensitive to and cause a corrective movement of the gates with the relatively large speed variation of not more than 0.06 percent of rated speed. Most modern governors are much more sensitive than that, some of them being guaranteed to be sensitive to 0.01 percent of rated speed.

The physical limitations of hydraulic turbines are such that an interval of time must pass after the governor flyballs have received a speed change impulse before the corrective movement can be transmitted back to the actual movement of the wicket gates. This period of time is usually about one-fourth of a second, but in case of worn or loose connections it may be much more. For this reason, it is impossible for hydraulic turbine governors to maintain constant speed with changing loads although ordinarily the extent of variation is of minor significance.

Elements of governing system

A modern governing system for a hydraulic turbine usually includes the following elements:

1. Governor head (speed sensing device).
2. A means of transmitting rotational speed of the turbine to the governor head.
3. A hydraulic power system consisting of a pilot valve and distributing valve system, hydraulic servomotors to operate the wicket gates, and a hydraulic power source.
4. A restoring connection between the wicket gates and the valve system.
5. A compensating dashpot (stabilizing means).
6. A blade control mechanism (Kaplan turbines only).

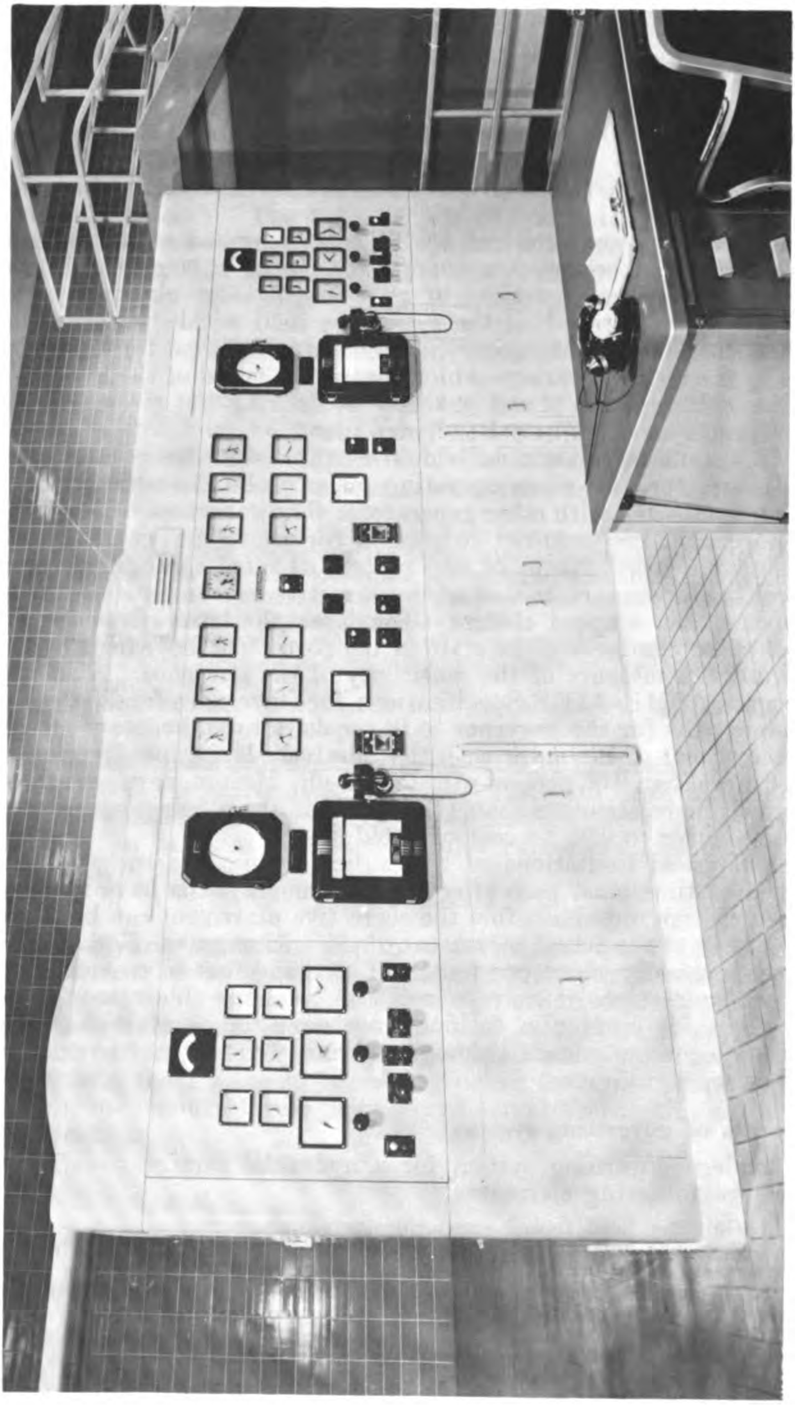


FIGURE 185.—*Twin governor cabinet for units 1 and 2—Watts Bar.*

Kaplan control mechanism

In plants where the turbines are the Kaplan type the governors include the Kaplan operating control mechanism (fig. 186). This mechanism consists of the Kaplan valve and restoring mechanism which supply the energy medium to the runner blade servomotor located in the main shaft. In order that the optimum relation between the runner blades and the wicket gates may be kept at all times, a cam and cam operating device are provided which operate as a function of the wicket gate position to actuate the runner blade valves. Consequently, when wicket gate adjustment is mentioned in the following discussions it also includes blade adjustment when the turbine is of the Kaplan type. The cam operating device is adjustable for different heads and is mechanically connected so that at all times the desired relationship may be held. An indicator is provided on the face of the cabinet to show the position of the runner blades.

Types of governors

There are three general types of governors—hydraulic, mechanical, and electrical. Of these, the mechanical and the electrical are somewhat cheaper than the hydraulic, but the hydraulic governor is more sensitive and adaptable to the speed controlling of hydraulic turbines; therefore, TVA specifies that all governors shall be hydraulically operated. Typical governor specifications are included in appendix A.

FACTORS AFFECTING TURBINE SPEED CHANGE

The factors affecting a speed change in a hydraulic unit when a change in load occurs are the kinetic energy of the unit by virtue of its mass and motion (WR^2 or flywheel effect), which will tend to resist any change in speed, and the rate at which turbine power output is changed. This latter factor is directly proportional to the rate at which the turbine wicket gates are moved to compensate for a given load change or, for a large instantaneous change in load, to the governor time, or the time required for the gates to open or close. For small load changes speed regulation is more dependent upon the governor sensitivity than the governor time because the wicket gates do not travel at the maximum rate but at some lesser rate determined by governor head. Any change in either the WR^2 or the governor time affects the amount of speed change for a given large load change. However, they both have their limits in the amount of change which is practical. Additional WR^2 over that which is inherent in a machine by reason of its normal weight and speed must be built extra into the machine and is expensive. Obviously, a shorter governor operating time will reduce the amount of speed change in a unit for a given load change, but this will be accompanied by a proportionately higher pressure rise. Therefore, the combination of governor time and WR^2 should be such as to produce the optimum combination of pressure and speed change. Figure 187 shows the recommended values of C for use in determining WR^2 required for good operation under different system conditions.

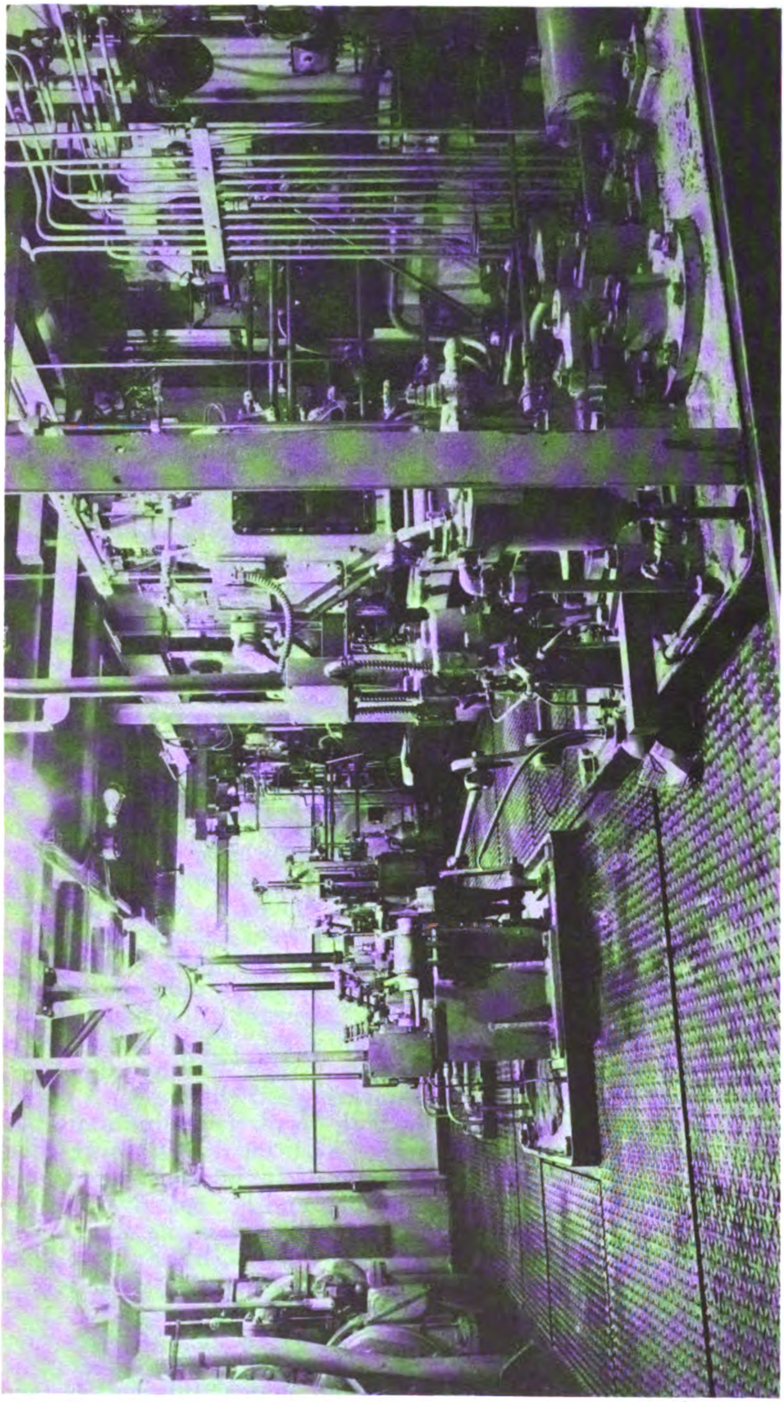
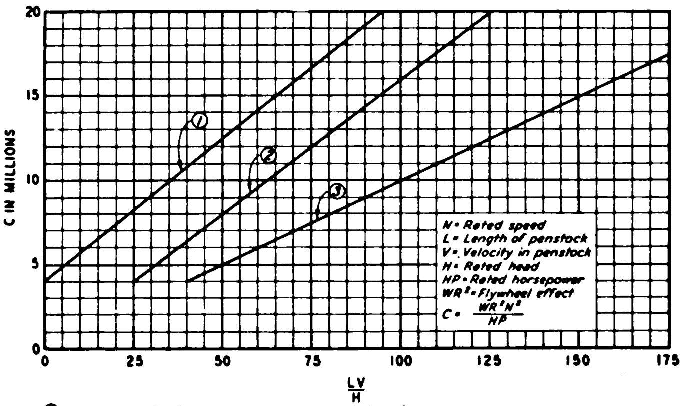


FIGURE 186.—*Interior view of Kentucky governor cabinet—Kaplan blade control mechanism at left center and governor head housing just to right of center.*



(1) *Lower limit of C for good operation on isolated load.*
(2) *Lower limit of C for good operation on interconnections if system load ≥ 4 x unit capacity.*
(3) *Lower limit of C for good operation on interconnections if system load ≥ 20 x unit capacity.*

FIGURE 187.—*Graph for determination of unit WR^2.*

The following formula is used for determining the approximate speed rise and WR^2 requirements of each unit:

$$N_2^2 - N_1^2 = \frac{64.4 \times 3600\left(\frac{HP_1 - HP_2}{2}\right)\left(\frac{H+h}{H}\right)^{3/2} \times 550 \times T}{WR^2 \times 39.5}$$

where,

N_1 = initial speed
N_2 = new speed
HP_1 = initial horsepower
HP_2 = new horsepower
H = initial head
h = surge head
T = governor time in seconds

This formula becomes inaccurate for large values of pressure rise and speed rise. Therefore, on units with long penstocks or where the pressure rise or speed rise is expected to be large, the arithmetic integration method is used for determining speed rise and pressure rise.[1]

TVA has attempted to hold the speed change of each individual machine when operating at rated head and rated horsepower, and with a governor time of 6 seconds for a full opening or closing of the turbine wicket gates within the following approximate limits:

Load change (percent of rated capacity)	*Speed change (percent)*
100	33
50	10
25	3

However, because of the many factors involved—penstock length, lack of surge tanks, permissible upper limit of WR^2, minimum governor time permissible, and pressure rise—this has not always been accomplished.

1 G. R. Rich, *Hydraulic Transients.*

PRINCIPAL FEATURES

Cabinets

In order to group all the various controls in one location, TVA specifies that all governors above 60,000-foot-pound capacity shall be of the cabinet-actuator type. The cabinet contains all of the governing equipment and auxiliaries with the exception of the pressure tank, which is usually located on the same floor and immediately behind the cabinets. The sump tank forms the base of the actuator cabinet and supports the control column, the distributing valve assembly, the auxiliary valve, the oil pumps, and other equipment. The control column carries the motor-driven governor head, the dashpot, the various controls and indicators, and the necessary connecting levers and linkages.

The entire mechanism is enclosed in a metal cabinet with the various controls and instruments mounted on its face. The actuator cabinet is also used for mounting auxiliary equipment such as temperature indicators and recorders, oil pressure gages, turbine flowmeters, alarm and signal devices, generator CO_2 release, head gate control switches, and telephones. The actuator cabinet is then a central control point from which an operator can control and monitor the various functions of the turbine and governor.

In plants where there is more than one turbine, the governing equipment is usually arranged so that two adjacent turbines can be controlled from a twin governor cabinet. This has the advantage of grouping the controls for two machines close together, and is somewhat cheaper because some of the governing equipment can serve both units. Figure 185 shows the front of a twin governor cabinet. Figures 186 and 188 show interior views of the Kentucky and Watts Bar governor cabinets. Note the blade control mechanism and governor head housing in figure 186.

Tank and pump capacities

The design of the governor is the responsibility of the governor manufacturer, but the arrangement and location of all auxiliaries are determined by TVA. In order that the manufacturer may be able to determine the size of the governor equipment, TVA specifies that the equipment shall have the following relative capacities:

Sump tank, ratio of volume (gallons) to volume (gallons) of pressure tank	0.6
Oil pump, ratio of capacity (gallons per minute) to volume (gallons) of servomotors	3.3
Pressure tank, ratio of volume (gallons) to volume (gallons) of servomotors	20.0

The system is designed to operate with oil under 250- to 300-pound-per-square-inch pressure. With the minimum oil pressure of 250 pounds per square inch the governor is required to operate the wicket gate one complete stroke (either opening or closing) in not more than 4 seconds.

Pumps

The oil pumps are motor-driven, self-priming, positive displacement type, each having a capacity against 300-pound pressure of not less than that specified in the relative capacities of the system.

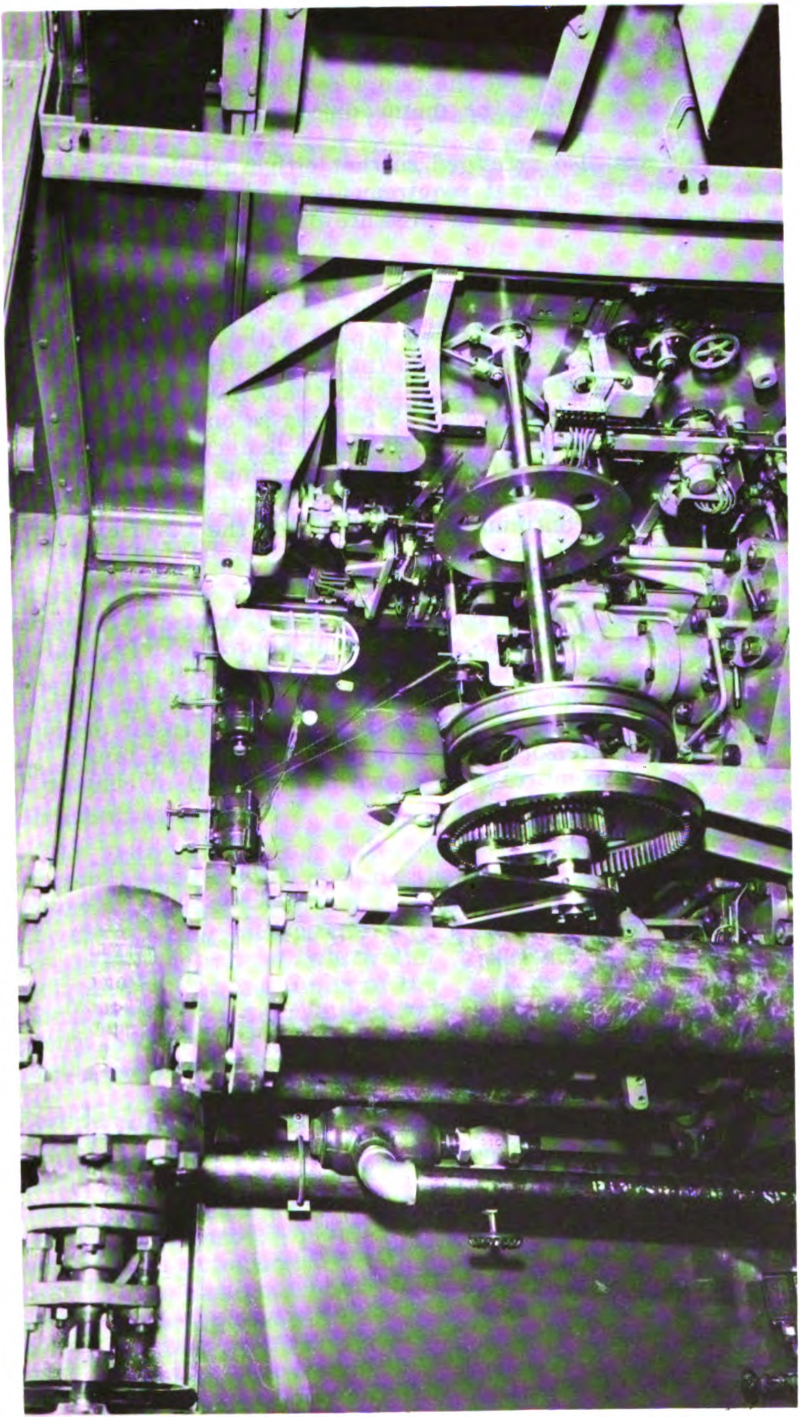


FIGURE 188.—*Interior view of Watts Bar governor cabinet at time governor was being tested—small motors, clamped to cabinet frame in upper center, with wires and pulleys are part of temporary testing apparatus.*

498128 O—60——26

Each pump is direct connected to its motor. The motors are 440-volt, 3-phase, 60-cycle, 40-degree centigrade, squirrel-cage, low-starting current, induction type designed for full-voltage starting. The controls are arranged so that the pump reaches full speed before it loads, and unloads before the motor disconnects from the power supply.

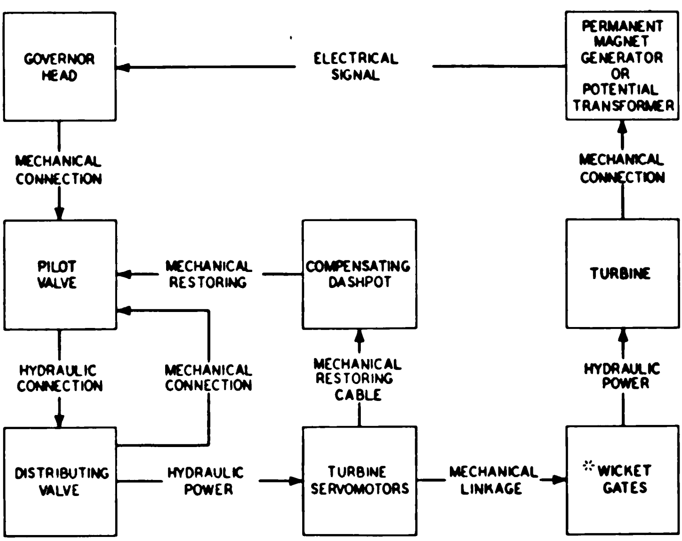
The controls are also arranged so that either pump may be operated to supply the normal requirements, with the second pump coming into operation if the oil pressure drops to a predetermined low.

Piping

The governor piping includes all piping within the cabinet and all piping between the governor and the pressure tank and between the governor and the servomotors. The oil velocities in the pipe are specified by TVA as not to exceed 18 feet per second, and all bends and fitting radii are long sweep. Van Stone flanges are used wherever possible. All pipes are seamless steel tubing, with the inside pickled and sandblasted and not painted. The piping arrangement is such as to permit continuous purification of the governor oil.

Compressors

As a part of the governor contract the manufacturer is required to furnish a motor-driven air compressor of approximately 8-cubic-foot-per-minute capacity when delivering against 300 pounds per square inch. The motor and compressor are mounted on a small receiving tank. This compressor is used to supply air to the pressure tanks and one compressor may serve several pressure tanks. A typical governor air compressor is shown in figure 211 of chapter 7, "Compressed Air Systems."



* For Kaplan turbines the blade adjustment is a function of the wicket gate adjustment

FIGURE 189.—*Governor and turbine block diagram.*

OPERATING CONTROLS

A cabinet actuator comprises the governor head, the pilot valve and distributing valve system, the restoring mechanism, the compensating dashpot, and some of the hydraulic power source (usually the pumps, sump tank, and connecting piping). Figure 189 shows a block diagram of a governor and turbine control system. Plate 14 and figure 190 are diagrams of a typical governing system.

Governor head

The heart of the governing system, the governor head, is a centrifugal speed-sensing device. Flyballs are used to measure speed changes and vibrators are incorporated to reduce the effects of static friction. The flyballs are driven by an induction-type synchronous motor operating at a speed which is directly proportional to the turbine speed. The power to drive the motor is supplied by a permanent magnet generator mounted on top of the generator shaft or from potential transformers connected to the generator main leads. The governor head is connected through a system of levers to the pilot valve.

Pilot valve

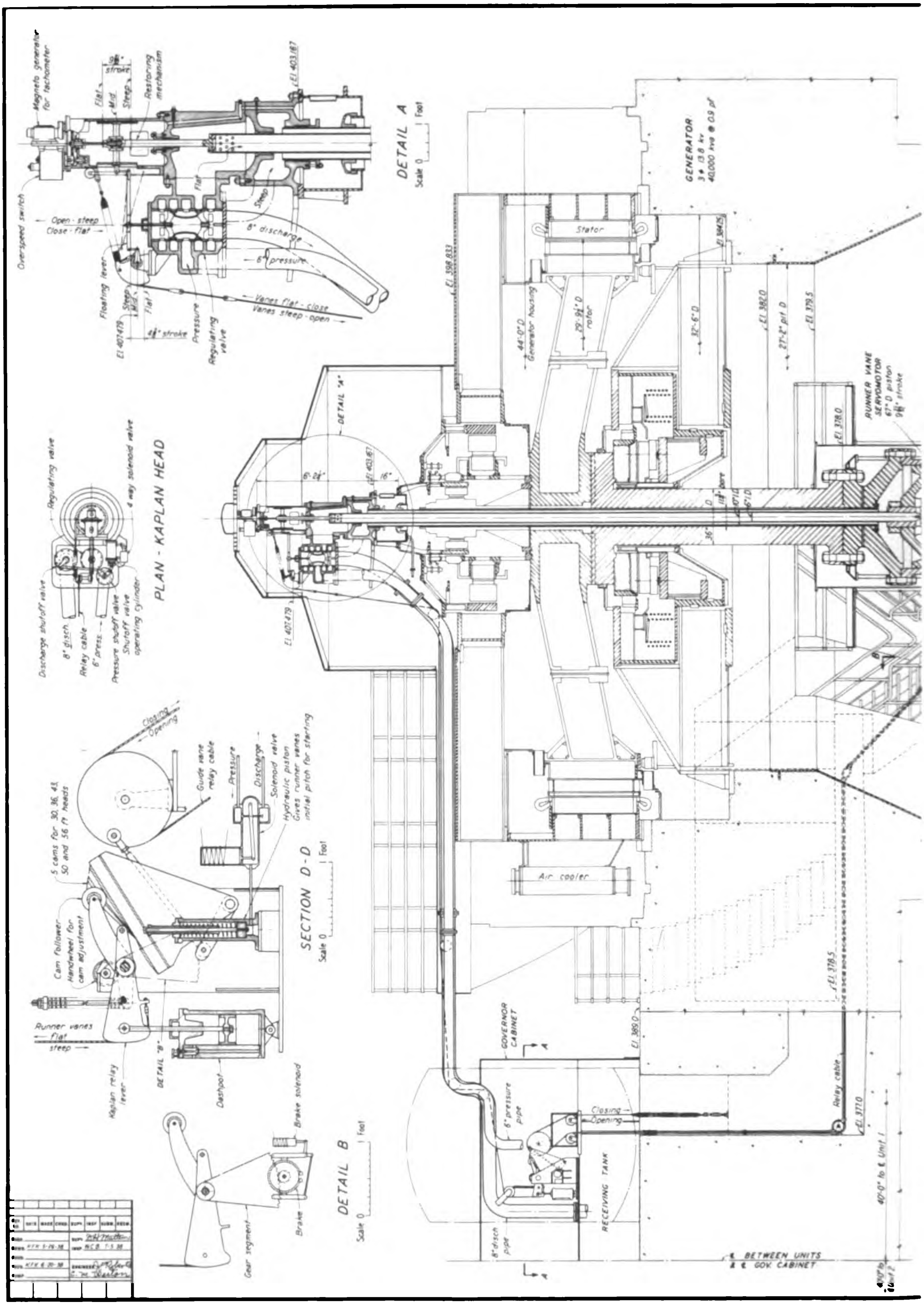
Because any appreciable loading of the governor head would have an adverse effect on the governor sensitivity, a small hydraulically balanced, 4-way, oil control pilot valve is used to actuate the main distributor valve. The pilot valve is connected into the pressure system and actuates a servomotor which is directly connected to the main distributing valve.

Distributing valve

The main distributing valve is a hydraulically balanced, 4-way oil control valve which controls the flow of oil to the turbine servomotors and thereby controls the position of the turbine wicket gates. The distributing valve is provided with an adjustable stop by which the maximum rate at which the wicket gates are moved may be controlled within the limits of the governor capacity. TVA usually specifies that the distributing valve and piping have sufficient capacity to operate the gates through a full stroke either opening or closing in a time of 4 seconds.

Compensating dashpot

In order to prevent free oscillation or "hunting" of the unit a mechanical feedback loop is provided from the turbine servomotors through an oil dashpot to the pilot valve. The dashpot contains two pistons, an adjustable needle valve, a mechanical bypass valve, and may contain automatic bypass valves or a solenoid-operated bypass valve. The dashpot introduces a temporary speed level setting change while the wicket gates are in motion. The speed level setting is then returned to its original setting by the dashpot as the wicket gates reach the desired position. Some of the governors have an additional feedback loop from the main valve to the pilot valve. The ratio of main valve movement to pilot valve movement is determined by an adjustment in this loop.


DETAIL A
GENERATOR
Stator
Air cooler
PLAN - KAPLAN HEAD
SECTION D-D
DETAIL B
GOVERNOR CABINET
RECEIVING TANK
RUNNER VANE SERVOMOTOR
Overspeed switch
Floating lever
Regulating valve
Pressure
Discharge
Solenoid valve
Dashpot
Brake solenoid
Brake
Gear segment
Kaplan relay lever
Cam follower
Relay cable
Closing
Opening
6" pressure pipe
8" disch pipe
Generator housing
40'-0" to ℄ Unit 1
℄ BETWEEN UNITS & ℄ GOV. CABINET

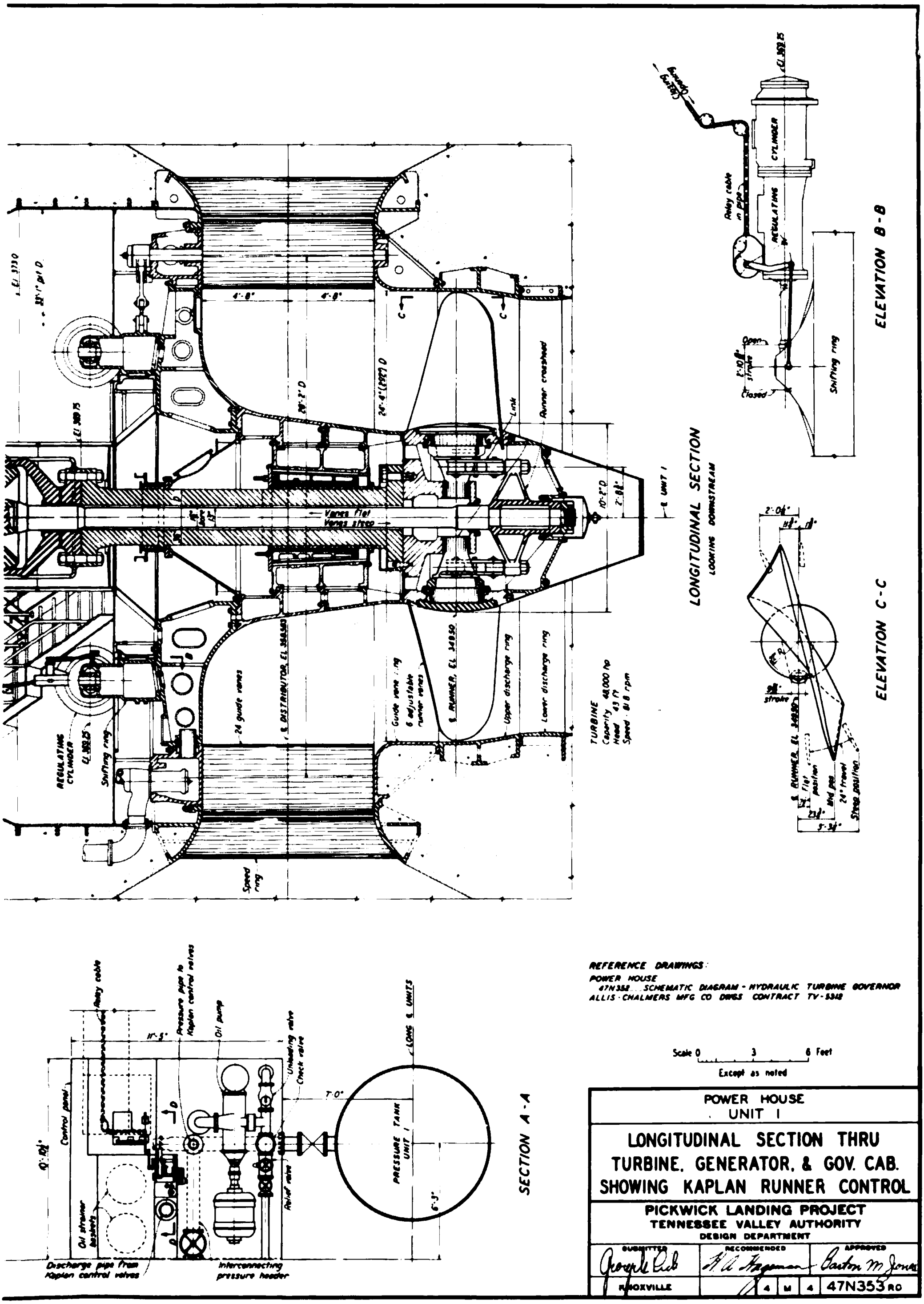

REFERENCE DRAWINGS:
POWER HOUSE
47N352 ... SCHEMATIC DIAGRAM - HYDRAULIC TURBINE GOVERNOR
ALLIS-CHALMERS MFG CO DWGS CONTRACT TV-5318
Scale 0 3 6 Feet
Except as noted
POWER HOUSE
UNIT 1
LONGITUDINAL SECTION THRU
TURBINE, GENERATOR, & GOV. CAB.
SHOWING KAPLAN RUNNER CONTROL
PICKWICK LANDING PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
47N353 RO
SECTION A-A
LONGITUDINAL SECTION
LOOKING DOWNSTREAM
ELEVATION B-B
ELEVATION C-C

PLATE 14

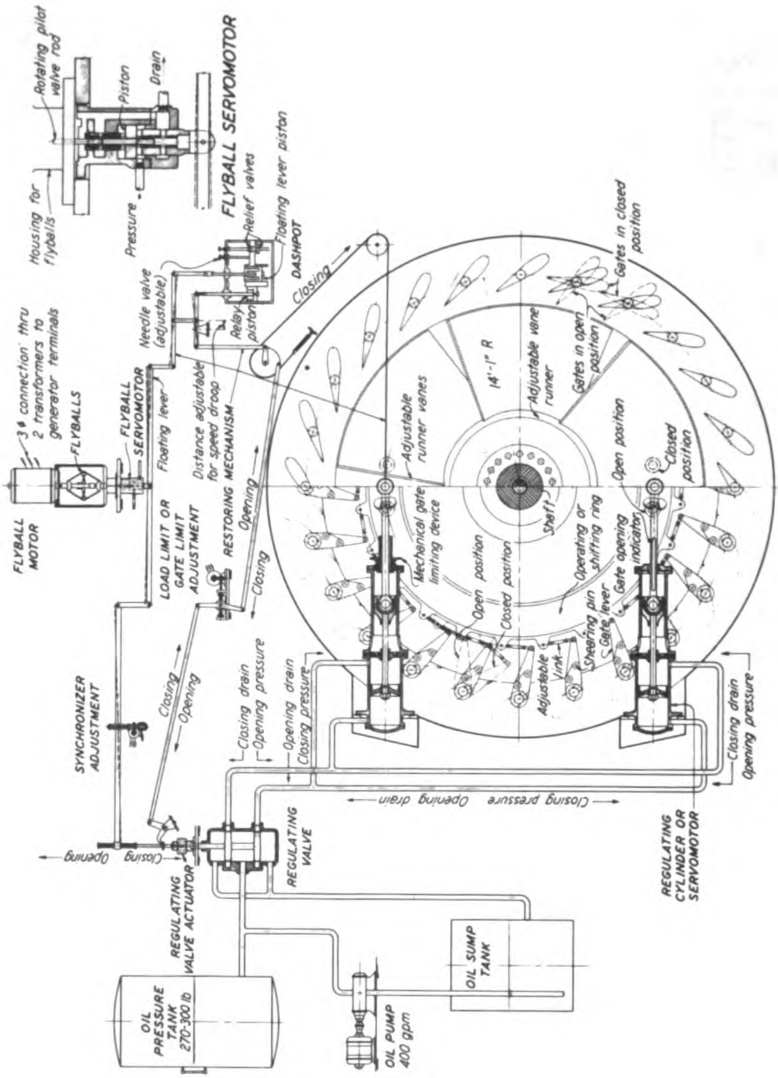


FIGURE 190.—*Schematic diagram of hydraulic turbine governor at Pickwick.*

Speed droop

In general there are two types of governors with respect to speed control. These are isochronous governors which hold a constant speed regardless of the prime mover load, and governors which have a speed droop mechanism. Governors which are equipped with speed droop mechanism will allow the speed to decrease as the load increases, and conversely the speed to increase as the load decreases. This is desirable in systems where several generating units are tied together electrically because it allows parallel or balanced operation of the several machines, whereas isochronous governors tend to hog the load and cause serious swings to occur between different machines, resulting in alternate overloading and unloading of the various machines. This condition is very undesirable and would result in serious operating difficulties.

The governors which TVA has purchased have an adjustable speed droop device with an indicator showing the amount of droop employed. The range of adjustment is from 0 to 6 percent droop from 0 to full gate, respectively. The control for this device is located on the face of the governor cabinet, and its operation consists of a mechanism which centers the main valve with the wicket gates in such a position as will produce a new speed of the prime mover corresponding to the load or wicket gate opening and speed droop employed. Therefore, this device makes the speed of the turbine a function of the gate opening and consequently for each change in load (gate position) the speed of the unit must be adjusted in order to maintain constant frequency of the power generated. This is accomplished by means of the synchronizer or speed-adjustment device and is sometimes done automatically by means of load-frequency control equipment.

Synchronizer

Each governor is equipped with a synchronizer or speed-adjustment device. This device changes the speed of the prime mover within very narrow limits, usually from 85 percent of rated speed at no load and 0 speed droop to 105 percent of rated speed at full load and maximum speed droop. It is manually adjustable from the face of the governor cabinet and automatically adjustable by a split-field motor from the main control board. This device changes the speed of the machine when synchronizing with the system and loads or unloads the machine. It operates through a system of levers which changes the position of the pilot valve plunger and causes the flyballs to assume a new normal position by an amount necessary to recenter the pilot valve.

Gate limit control

The wicket gate limit control is located on the face of the governor cabinet and is manually adjustable. It is also equipped with a split-field motor which may be electrically operated from the main control board. The mechanism serves two purposes: (1) to open or close the gates to give the desired speed or load when operating on the auxiliary valve and (2) to prevent the gates from opening beyond a predetermined position when operating on the main distributing valve. The gate limit mechanism operates through a sys-

tem of levers to prevent the pilot valve from opening and thus prevent the distributing valve from causing the servomotors to open the wicket gates when the wicket gates reach the gate limit control setting. The unit may be operated at "blocked gate" by setting the gate limit control to the desired gate position and advancing the synchronizer until the gates are blocked against the gate limit. The governor head has little control over the gate opening for this type of operation except for large speed increases.

For auxiliary valve operation the gate position is determined by the gate limit control through the auxiliary distributing valve and restoring mechanism.

Auxiliary valve

The auxiliary valve is a hydraulically balanced, 4-way oil control valve much like the main distributing valve except smaller. When in operation it provides manual control of the wicket gates through the gate limit control on the face of the cabinet. Auxiliary valve operation permits the governor head and main valve to be removed for maintenance or repair. Selection of auxiliary valve or main valve control is by means of a transfer valve with control and indicator located on the face of the cabinet.

AUXILIARY EQUIPMENT

In addition to the equipment which is an integral part of the governing mechanism, TVA requires that the governor manufacturer furnish certain auxiliary equipment as well as mount certain other equipment furnished by the generator manufacturer, the turbine manufacturer, and TVA on the face of actuator cabinet. The equipment furnished by the governor manufacturer usually includes shutdown and speed-no-load solenoids, tachometer, overspeed switches, generator brake applicator, turbine flowmeter, temperature recorders, and other necessary switches, and pressure gages. The equipment furnished by others and mounted on the actuator cabinet includes generator guide bearing thermometer, generator thrust bearing thermometer, thrust bearing oil level indicator, annunciator cabinet, signal cabinet, CO_2 fire-protection control switch, draft tube pressure gauge, turbine guide bearing thermometer, turbine bearing oil pump control switches, and head cover pressure gage.

Shutdown solenoid

Each governor is provided with a shutdown solenoid and a speed-no-load solenoid which operate in response to various protective devices and emergency switches. The shutdown solenoid operates to shut down and lock out the turbine and requires that the trouble be corrected and the solenoid manually reset before the unit can be restarted. The speed-no-load solenoid operates to close the wicket gates to the speed-no-load position and automatically resets upon restoration of normal conditions.

Tachometer

Each governor is equipped with a tachometer with two indicators for measuring the speed of the unit. One indicator is mounted on the face of the actuator cabinet and one is located on the main con-

trol board in the control room. The tachometer drive is mounted above the generator pilot exciter and is driven from generator main shaft. The tachometer is arranged to give indication when the unit starts to rotate and just prior to its coming to a dead stop.

Overspeed switch

Each unit is equipped with an overspeed device which functions to shut down the turbine when a predetermined overspeed has been reached. This device consists of a mercury switch mounted above the generator pilot exciter. It is mechanically connected to the main shaft and electrically connected to the shutdown solenoids located in the governor cabinet.

Generator brake applicator

Each governor is equipped with either a manual or an automatic generator brake applicator. The manual brake applicator consists of a valve operated by a knob on the front of the actuator which admits air at approximately 100 pounds per square inch to the generator brakes. The automatic brake applicator is arranged so that when the speed of the unit drops to 50 percent of normal the brakes are applied intermittently for a selected number of cycles, then constantly until the unit has stopped. The generator brake control is provided with a duplex pressure gauge which indicates station air pressure and pressure applied to the brakes.

Turbine flowmeter

Each unit is equipped with a turbine flowmeter which is actuated by Winter-Kennedy-type piezometer taps located in the spiral case. The flowmeters purchased since 1952 are of the radial-torque type and are adjustable as to pressure differential required for full scale deflection. Each flowmeter is arranged for transmitting its reading to a remote indicator and integrator also usually furnished by the governor manufacturer. The remote indicator and integrator, which is mounted in the control room, is arranged to totalize the flow at all the units in the plant.

Gages and instruments

In addition to the equipment mentioned above, the following is a typical list of equipment furnished by the governor manufacturer and mounted on the face of the actuator cabinet:

1. 12- or 16-point temperature recorder for recording the various bearing temperatures, generator temperatures, and cooling water temperatures.
2. 3-pen mercury-actuated recording thermometer for recording generator cooling water inlet and discharge and thrust bearing cooling water discharge temperatures.
3. Pressure gage for generator cooling water supply.
4. Pressure gage for station service air.
5. Duplex pressure gage to indicate forebay and spiral case water pressure.
6. Synchronous clock.
7. Control switch for tailwater depressing system.
8. Turbine start-stop control switch.
9. Emergency shutdown control switch.
10. Head gate control switch.
11. Generator housing heater control switch.
12. Annunciator test and reset switch.

REMOTE CONTROL EQUIPMENT

TVA has completed or has under construction remote control equipment for 47 units at 17 plants at which the turbine is controlled from a remote point, either the control room of the plant involved or the control room of a nearby plant. As of January 1, 1958, estimates have been prepared covering the addition of remote controls for the two units at Apalachia.

At these plants the remote operator initiates the automatic starting of the auxiliaries and of the unit, automatically synchronizes, loads the unit and—when the occasion warrants—shuts down the plant. He receives verification of each control operation as he performs it and has before him a limited number of indications such as gate position, gate limit position, turbine flow, speed, volts, amperes, kilowatts, and kilovars. Manual control facilities are provided for complete manual operation if desired in an emergency or for testing the unit.

Control of the synchronizer and gate limit mechanisms is accomplished by means of a split-field motor which is controlled from the main control board.

The gate position and gate limit indicators are provided with either a transmitter motor or potentiometer for transmitting these indications to the control point. The tachometer is so arranged that no alterations are necessary for remote indication.

Draft tube tailwater depression for condenser operation is accomplished automatically by means of a gate position switch. This switch operates a solenoid valve which admits air to the draft tube when the wicket gates are closed and the generator breaker is closed.

ERECTION

The completed governor is assembled in the contractor's shop and comprehensive shop tests are performed to ensure the proper functioning of the various parts.

The field erection of the governors is by TVA forces with all final adjustments and settings being made under the supervision of the contractor's erection engineer. Prior to placing a unit into operation, the turbine wicket gates are set to operate from closed to open and open to closed in the desired time, usually 6 to 8 seconds in each direction. The ability of the governor to control the speed of the turbine at speed no load is tested and adjustments are made if necessary. "Off-the-line" frequency of not more than plus or minus 0.1 cycle is considered satisfactory.

TESTS

Load rejection tests are made on all turbines and governors to determine the ability of the governor to handle the machine in the event of an accidental loss of load. These tests consist of loading the generators in 25 percent increments, and then manually opening the circuit breaker switch. During this test, certain gages and instruments are read and recorded. Graphic time recordings are also made of the gate movement, the main valve movement, and the speed in cycles. From these observations and recordings it is determined if the governor requires further adjustments. Field adjustments are always necessary in order to obtain the desired regulation. A typical load rejection test report is included in appendix A.

Chapter 5

AUXILIARY POWER GENERATORS

Normal sources of station power for hydroelectric plants usually consist of one or more service transformers connected to the main power transformer busses where they can be energized either from the station generators or from the transmission system through interconnecting ties with other power stations. Under normal operating conditions, these several auxiliary power sources are considered dependable both as to sufficiency and continuity of service. There exists, however, the remote possibility of simultaneous loss of all station generation and transmission facilities, particularly during time of high flood. This possibility was not considered too remote during the early years of TVA to warrant not providing an emergency source of auxiliary power for operation of essential plant auxiliaries at 11 plants. These plants were all built or under construction during the period 1933–42 when the system plants and interconnecting ties were much fewer than exist today. Gasoline-engine-driven generator units were the emergency sources of auxiliary power installed at these 11 plants which are listed in table 5 together with pertinent data covering the emergency units.

Essential plant auxiliaries

The essential plant auxiliaries are those necessary for the safeguarding of structures, equipment, and personnel. They include station drainage pumps, spillway gate gantry cranes and hoists, governor oil pumps, and battery charging generators for emergency lighting. The station drainage pumps, which handle all leakage and drainage from the galleries of the powerhouse substructure, are vital to operation of the plant from the standpoint of flood protection.

TABLE 5.—*Emergency auxiliary power generating units*

Project	Gasoline engine rating					Generator rating (0.8 PF)				Exciter rating	
	Bhp	Rpm	Cylinders			Kva	Phase	Cycles	Volts	Volts	Amps
			No.	Bore (inches)	Stroke (inches)						
Kentucky	565	1,200	8	8	9	400	3	60	480	125	40
Pickwick	565	1,200	8	8	9	400	3	60	480	125	40
Wheeler	290	1,200	8	6½	7	200	3	60	2,400	125	24
Guntersville	425	1,200	6	8	9	300	3	60	480	125	40
Chickamauga	425	1,200	6	8	9	300	3	60	480	125	40
Watts Bar	425	1,200	6	8	9	300	3	60	480	125	20.6
Fort Loudoun	410	1,200	6	8¼	9	300	3	60	480	125	40
Cherokee	290	1,200	8	6½	7	200	3	60	480	125	24
Douglas	290	1,200	8	6½	7	200	3	60	480	125	24
Fontana	180	1,200	6	6	7	125	3	60	480	125	16
Ocoee No. 3	71	1,200	6	4⅝	4¾	35	3	60	480	125	12

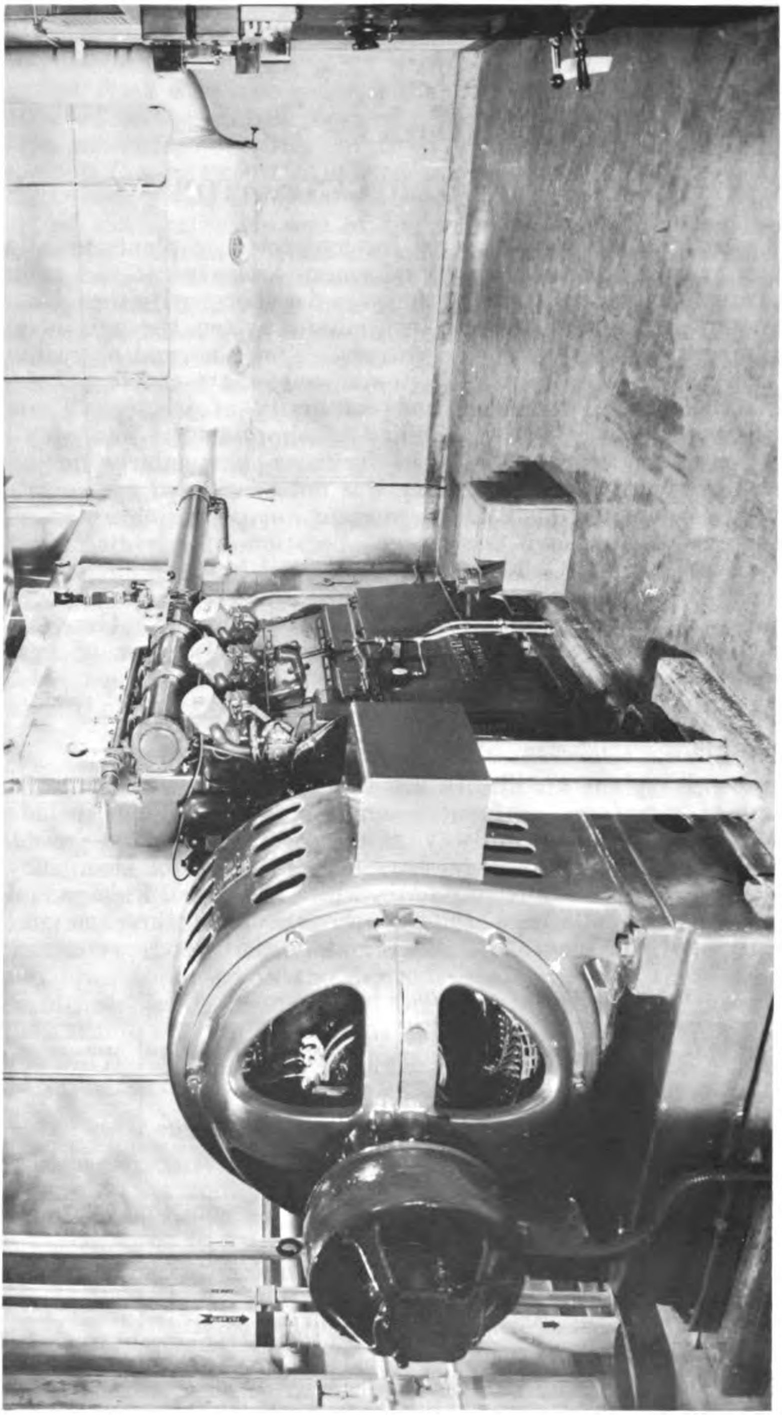


FIGURE 191.—*300-kilovolt-ampere emergency auxiliary power generator at Guntersville—muffler at upper right.*

It is imperative that the spillway gates be operable during flood periods to regulate the stream flow. The governor oil pumps, which control the turbine by opening and closing of the wicket gates, must necessarily be in operating condition at all times. A limited amount of lighting is also considered essential in certain areas to ensure safety to operating personnel.

Capacity

The capacity of the emergency generator unit is not sufficient to provide power for simultaneous operation of all essential plant auxiliaries. The rating of the unit is based upon continuous operation of one or more station drainage pumps with a small emergency lighting load, and intermittent operation of one spillway gantry crane or hoist and one governor oil pump, or the governor oil pump by itself. Drainage pump motors range from 10 to 200 horsepower, depending upon the size and operating heads of the pumps in the various stations. Each spillway hoist or gantry crane is equipped with motors which vary in rated capacities from 40 to 100 horsepower at the different plants. Governor oil pump motors also range from 40 to 100 horsepower, in accordance with the size and operating characteristics of the turbines. An allowance of approximately 25 horsepower is made for emergency lighting in the powerhouse, lock, and switchyard areas. At several plants the machines also have sufficient capacity for operation of passenger and employee elevators. The rated capacities of the engine-generator units installed in the various plants are shown in table 5.

Location

With the exception of the unit installed at the Ocoee No. 3 project, all machines are located within the powerhouses. Each machine, consisting of a gasoline engine direct-connected to an alternating-current generator mounted on a common base plate, is installed in a separate room of the powerhouse. Figures 191, 192, and 193 show typical auxiliary power generator installations and figure 194 illustrates a typical room arrangement.

The room, which is of fireproof construction, includes a built-in automatic carbon-dioxide fire-extinguishing system of the total room flooding type. This system, which automatically operates by functioning of thermostats placed at the ceiling, also may be actuated manually. A metal self-closing fire door is provided, which may be closed either by operation of a pressure trip in the CO_2 system or by the melting of a fusible link in the counterweight cable which holds the door in its normally open position. Ventilating fans are stopped and room dampers are closed also by functioning of the CO_2 fire-protection system. TVA does not permit the storage of gasoline within this room.

The unit which is installed at the Ocoee No. 3 project as an emergency source of power for operation of the spillway gate hoists and provision of a small amount of lighting is located at the dam. At this project the normal power supply to the dam is over a single 12.45-kilovolt pole line from the powerhouse, which is several miles distant. This unit is protected from fire by portable hand-type fire extinguishers. A view of this small unit is shown in figure 80, page 142.

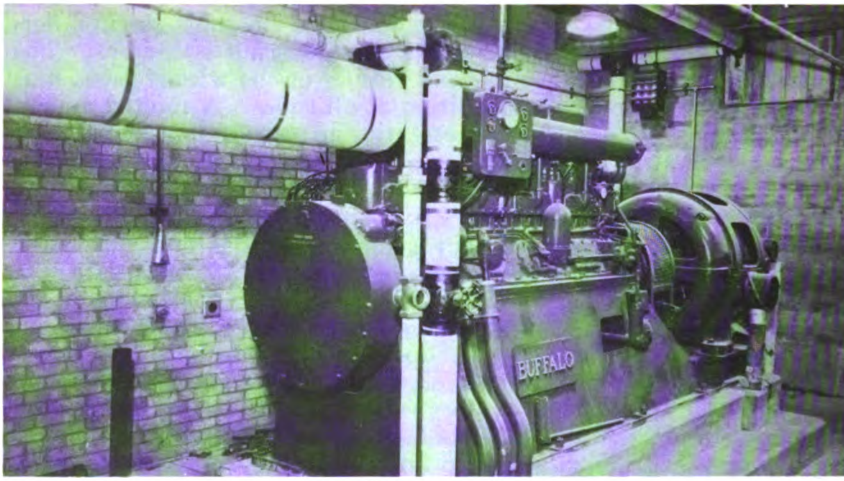


FIGURE 192.—*200-kilovolt-ampere auxiliary power generator at Cherokee—water-cooled exhaust at upper left.*

Fuel supply

Each auxiliary power generator is supplied with gasoline from a steel storage tank which is usually buried in the fill outside the powerhouse wall. A typical gasoline fuel system is presented in figure 195. The tank is placed at an elevation which is a foot or more below the engine base so that a break in the supply line will not flood the engine room floor with gasoline. The tank, which is sized to provide a 3- or 4-day supply, is purchased with unpainted interior and a coating of bituminous enamel on the outside. Frequently, the tank is placed in the fill on the downstream side of the powerhouse where it is subject to floatation during periods of high tailwater. In such cases it is securely anchored to concrete footings or walls. A 2-inch gravity fill line is connected to a fill box which is placed in a roadway or the powerhouse entrance where it may be serviced by tank truck. The storage tank is also provided with a vent line which terminates at the filling point with a flameproof vent cap. A remote reading level gage, which indicates the contents of the tank in gallons, is located in the engine rooms.

A ¾- or 1-inch-diameter brass or copper supply line is embedded through the concrete from the tank to the fuel pumps located on the engine. Two parallel operating foot valves are installed on the suction line within the tank as double protection to ensure a supply at all times. A relief valve is also installed on the suction line within the tank, which limits the pressure to which the line may be subjected during periods when it may be cleaned by blowing out with compressed air. A return line is connected between the engine and tank to drain all unburned fuel which accumulates in the carburetor flood cups, or is relieved from the pumping system, back to the supply tank.

A pressure and vacuum gage is installed on the supply line near the engine to assist the operator in determining when the storage tank has been filled to the proper depth, as it is possible that a care-

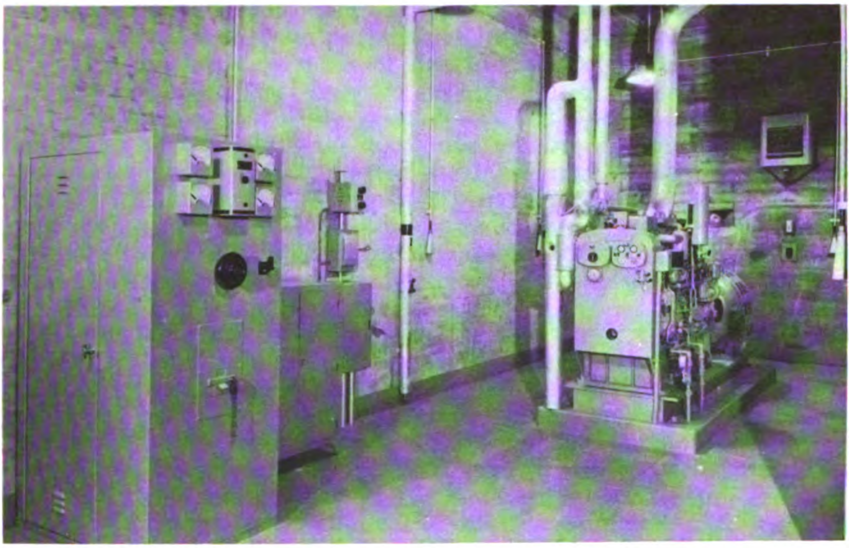


FIGURE 193.—*125-kilovolt-ampere emergency auxiliary power generator at Fontana—at left are the electrical control panel, battery cabinet and charger in that order from left to right.*

less filling may overflow the tank through the fill pipe, thereby placing the supply line under a positive pressure and creating a fire hazard if breakage occurred. A vacuum reading on this gage will also assure the operator that the engine fuel pumps are functioning properly and that there are no leaks in the supply line. A drain line with two locked valves in series is provided for each tank for use in removing any water which may accumulate in the bottom due to condensation or for any other reason.

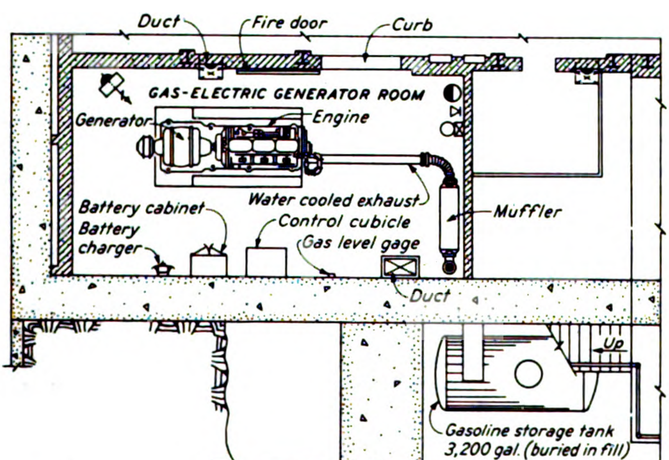


FIGURE 194.—*Typical equipment layout for 300-kilovolt-ampere auxiliary power generator—Watts Bar.*

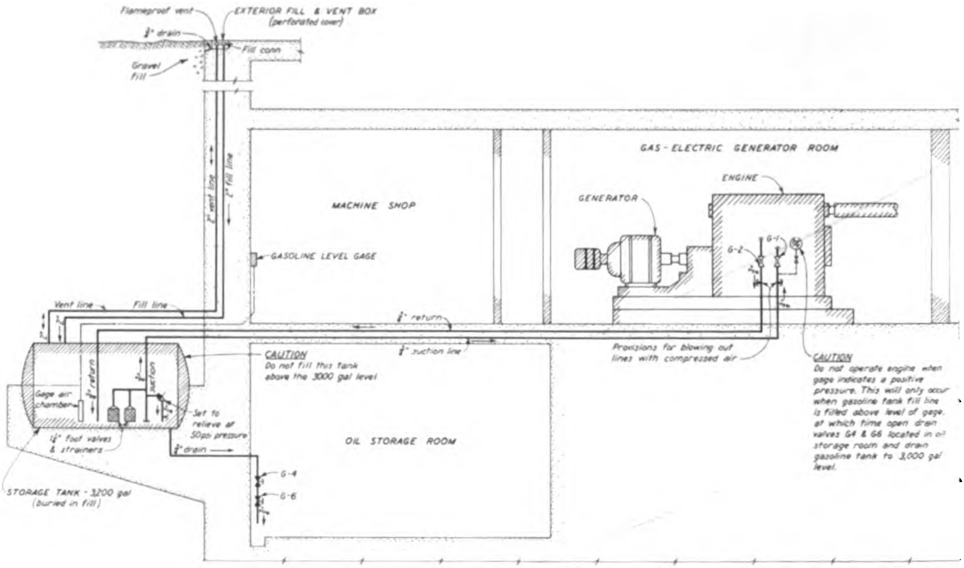


FIGURE 195.—*Typical gasoline fuel system for auxiliary power generator.*

The entire fuel system is designed to conform to the requirements of the National Board of Fire Underwriters. Two diaphragm-type pumps are mounted in parallel on the supply line at each engine. One pump is engine driven and the other is hand operated for starting the unit. Copper tubing is connected between the carburetors and the discharges of the pumps. Flexible hose sections are provided in both the return and supply lines between the engine and the point of embedment.

Engines

The engines of the auxiliary power generators installed in the several plants range in size from 71 to 525 brake-horsepower and are of the horizontal shaft, multicylinder, 4-cycle, water-cooled type, with enclosed flywheel, lubricating oil pump, full-pressure lubricating system, starting motors, throttle governor, mechanical overspeed device, and a flexible coupling between the engine shaft and the generator shaft.

Exhaust manifolds are fully water-jacketed and each engine is provided with a muffler (fig. 191) and water-cooled exhaust section (fig. 192). The exhaust line which is insulated and supported by spring hangers to accommodate expansion is routed upward through the powerhouse structure and is discharged above the roof level. Cooling water for the engines is supplied from the plant raw water service system. Where possible engine cooling water is supplied by gravity, but in some cases it was necessary to use engine-driven pumps. Cooling water systems are provided with thermometers, pressure gauges, sight-flow indicators, and a pressure switch interlocked with the ignition system which will stop the engine and sound an alarm on failure of the cooling water supply. These pressure switches, which are usually mounted on the cooling water pump

discharge, have a foot-operated bypass switch to permit starting of the engine when there is no pressure in the cooling water system.

Engine flywheels are made of steel and are fully enclosed. Crankshafts are 1-piece, heat-treated, steel forgings, with crankpins and journal bearings uniformly ground and polished. Crankcases have handholes on both sides for inspection and replacement of bearings. Camshafts are also heat-treated steel forgings, with the cams integral with the shaft and bearings ground and polished. All bearings are bronze or babbitt, or an antifriction type. Pistons are specified to be of aluminum or aluminum alloy, but during World War II it was necessary in a few cases to substitute cast iron when the use of aluminum was restricted.

All moving parts, bearings, gears, and chain drives are lubricated automatically from a self-priming pumped system which includes an oil filter, pressure gage, level indicator and, frequently, a water-cooled oil cooler. A minimum of two carburetors, with air cleaners, backfire arresters, and flood cups are furnished on each engine.

Ignition systems are of the dual type, operating from duplicate sets of 12-volt storage batteries. Each engine is equipped with a battery-charging generator, with voltage regulator and magneto cut-out. Storage battery cabinets are also furnished and each unit has a battery trickle charger, battery selector switch, charger selector switch, and ammeter.

The starting motor, or motors, operate from the storage batteries through a magnetic contactor and push button which is interlocked with the engine spark control lever to prevent starting unless the spark is fully retarded.

The engine instrument panel contains spark and throttle controls, oil pressure gages, ignition switch, starting motor push button, speed indicator, and a battery panel lamp.

Typical procurement specifications for the engine, generator, and assorted control equipment are given in appendix B.

Generators and exciters

Generators for the auxiliary power installations are of the horizontal shaft, direct-connected type, with squirrel cage, amortisseur windings and with direct-connected, shunt-wound, self-excited exciters. The nominal ratings of the various generators and exciters are shown in table 5. All generators are 480 volts, which is the voltage of the auxiliary power system, except at Wheeler where a 2,400-volt generator is provided because the main auxiliary bus voltage is 2,400 volts. This voltage is due to the long feeders required to the lock and village. However, the power station auxiliaries at this plant are 480 volts. In addition to the specified nominal ratings, each generator is required to have sufficient capacity for starting the largest rated auxiliary unit to be operated during an emergency.

The generators, exciters and appurtenances conform to the standards, codes, and rules of AIEE and NEMA as to material, construction, operation, and testing. The temperature rise of the generators and exciters is limited to a 50 centigrade rating. Exciters are of sufficient capacity to supply field excitation current to the generators when they are operated at normal rated kilovolt-ampere output, 80 percent power factor, and normal rated voltage.

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Control equipment

Each emergency generator unit is provided with a control switchboard on which is mounted an automatic voltage regulator used to vary the exciter shunt field current to maintain the generator voltage constant with variations in load. An exciter field rheostat is also supplied for each unit for setting the range of the regulator. Also mounted on this switchboard are alternating- and direct-current voltmeters and ammeters, a field switch, discharge resistor, and an enclosed-type generator circuit breaker. A typical control panel or switchboard is shown in figure 193.

Shop assembly and tests

Each complete auxiliary power generator and accessory equipment are shop assembled and tested. The shop tests generally include the following:

1. An engine test at 100 percent of its specified continuous horsepower rating for 2 hours, using water brake.
2. Combined engine and generator test at full load for 48 hours.
3. Combined engine and generator test to determine the maximum capacity at rated speed.
4. Tests to determine the fuel consumption per kilowatt-hour generated at one-half, three-fourths, and full rated load of the generator.

Certified copies of these tests are submitted to TVA for approval prior to releasing the equipment for shipment.

After installation, such tests are conducted by TVA as are deemed necessary to demonstrate the compliance of the equipment with the specifications. These tests usually include the satisfactory starting of the largest auxiliary motor in the particular plant for which the machine was specified. To date all emergency generator units have satisfactorily met the field tests conducted.

Each unit, which is started from its own battery, is not synchronized with the system. It is connected to the auxiliary power main bus and, generally, to the air-conditioning load by three switches so arranged that the unit can carry the air-conditioning load for the purpose of routine weekly testing.

Chapter 6

ELEVATORS

Elevators are provided at hydro plants where considerable differences in elevation exist between operating areas. For this reason, they were installed in 13 of the 20 hydro projects built by TVA. At all but 1 of these 13 projects 1 elevator is sufficient for both the operating personnel and the visiting public. At the other plant, for reasons given in the next paragraph, 3 elevators were installed. Table 6 lists the 13 plants and gives pertinent data covering the 15 elevators installed in them.

At Watts Bar hydro plant three elevators are required due to the physical arrangement and separation of the power generating and control facilities. The control building at this project is located on a steep bluff overlooking the powerhouse. It is connected to the powerhouse by a vertical shaft sunk in the rock bluff some 100 feet deep and a tunnel approximately 135 feet long. One employees' elevator and one public elevator are installed in the vertical shaft, this being the main and most convenient access for visitors to reach the powerhouse. An additional employees' elevator is installed in the powerhouse for the benefit of the plant operators who also attend the screen well house which provides condenser water to the steam plant located downstream from the hydro plant. Figure 196 shows the lobby entrance to the public elevator in the Watts Bar control building, and figure 197 shows the physical arrangement of both control building elevators.

At Norris, Cherokee, and Douglas, which are relatively high storage dams, elevators were placed in the dam, with an adit or tunnel joining the powerhouse. At these plants the elevators provide ready access for the employees between the galleries in the dam, the top of the dam, and the powerhouse. Passenger elevators are installed in the powerhouses at Kentucky, Pickwick, Chickamauga, Fort Loudoun, and Fontana, and in the control building at Wheeler. These elevators are also used for routing visitors through the plants. At Hiwassee there is a service elevator in the powerhouse, and at Watauga and South Holston elevators are installed in the sluiceway towers for use of employees.

Most of the elevators are driven and controlled by direct current provided by a motor-generator set and 250-volt variable voltage control equipment. Such direct current installations give smooth operation characteristics. Principally because of wartime restrictions, however, a few elevators had to be supplied with alternating-current drive motors and controls, and do not operate as smoothly as the others. All the machines are the traction type with automatic control and self-leveling devices. With the exception of the Fontana elevator, all machines are overhead drive units (fig. 198). The Fontana elevator has a basement drive, as shown in figure 199, due

TABLE 6.—*Automatic electric elevators*

Project	Service	Location	Live load (pounds)	Speed (feet per minute)	Total lift (feet)	Number of landings	Car area (square feet)	Hoisting machine			Motor-generator set			Buffers (type)
								Type	Location	Motor (horsepower)	Motor (horsepower)	Generator (kilowatts)	Exciter (amperes)	
Kentucky	Passenger	Powerhouse	2,500	300	81	6	33	Geared	Overhead	25	23	15	6.8	Oil.
Pickwick	do	do	3,000	250	89.5	7	47	do	do	25	25	18.6	12	Do.
Wheeler	do	Control building	5,000	250	70.25	6	56	Gearless	do	30	40	25	12.5	Do.
Hiwassee	Service	Powerhouse	1,500	20	22	3	30	Geared	Basement	7.5	(1)	(1)	(1)	Spring.
Chickamauga	Passenger	do	5,000	250	81	6	54	Gearless	Overhead	30	40	25	14	Oil.
Watts Bar	do	Control building	5,000	350	114	4	44	do	do	41	35	21	18	Do.
	Employee	do	2,000	350	114	4	12	Geared	do	23.5	23	21	6.8	Do.
	do	Powerhouse	2,000	200	42	4	24	do	do	13.5	15	15.4	6.8	Spring.
Fort Loudoun	Passenger	do	5,000	100	56	6	45	do	do	20	(1)	(1)	(1)	Do.
Norris	do	Dam	3,000	250–300	181.48	4	36	do	do	25	(2)	(2)	(2)	Oil.
Cherokee	do	do	5,000	250	99.6	3	48	Gearless	do	29	45	23	14	Do.
Douglas	do	do	5,000	250	80.6	3	48	do	do	29	45	23	14	Do.
Fontana	do	Powerhouse	2,500	60	34	3	37	Geared	Basement	6	(1)	(1)	(1)	Spring.
Watauga	Employee	Sluiceway tower	1,200	100	225.35	2	18	do	Overhead	5	(1)	(1)	(1)	Do.
South Holston	do	do	1,200	100	196.8	2	18	do	do	5	(1)	(1)	(1)	Do.

[1] None—A.-C. drive. [2] None—2-speed A.-C. drive.

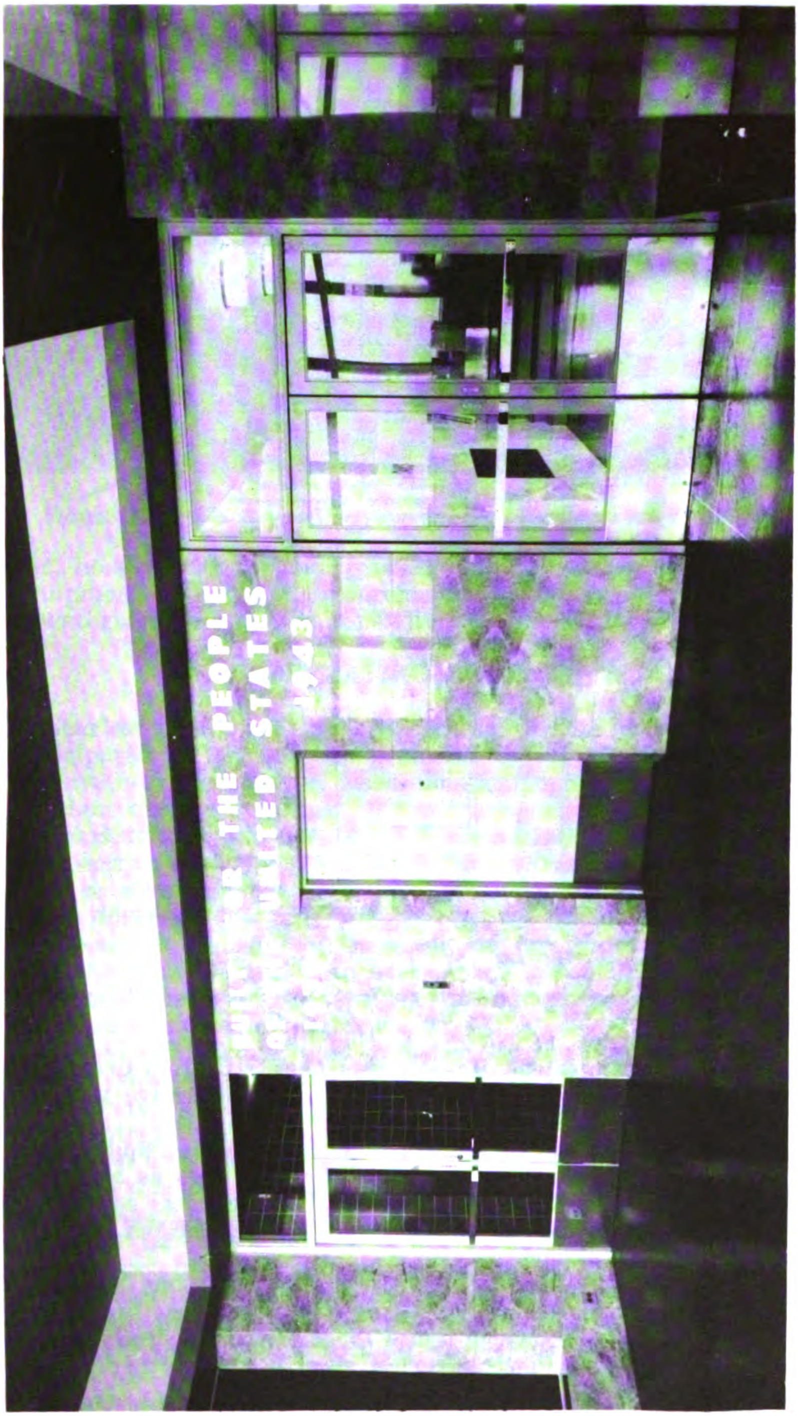


FIGURE 196.—*Public elevator entrance in center of control building visitors lobby—Watts Bar.*

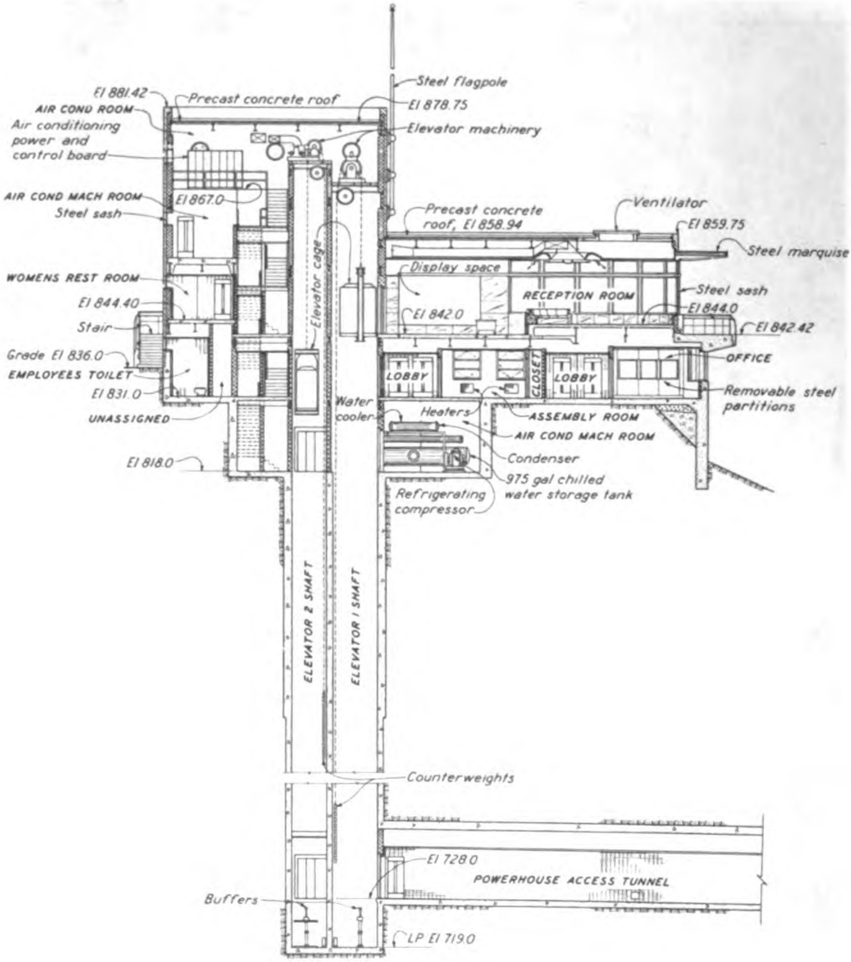


Figure 197.—*Arrangement of employee and public elevators in control building—Watts Bar.*

to the physical arrangement of the powerhouse. Bottom drive machines are avoided where possible because of the excessive wear on cables occasioned by the extra number of reverse bends.

Equipment and work are specified to conform to the requirements of the American Standard Safety Code for Elevators as approved by the American Standards Association. The electrical equipment furnished must conform to the standards of AIEE, NEMA, and the Underwriter's Electric Code.

TVA furnishes the hoistway and the machinery room, including main steel beams supporting the hoisting equipment. A typical machinery room layout is shown in figure 198. All service feeder wires, embedded conduits and junction boxes, main powerline switch, and a telephone unit for the car are also furnished by TVA.

The elevator contract covers the furnishing, installing, and testing of the complete elevator, including all hoisting machinery, guides,

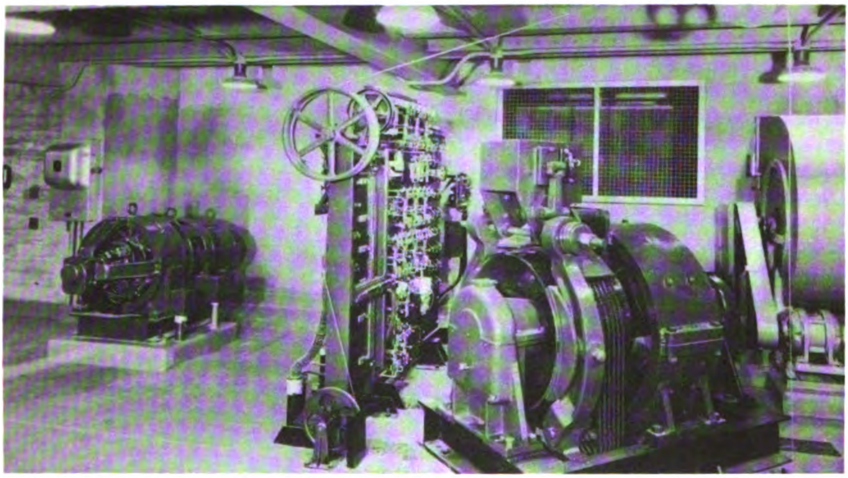


FIGURE 198.—*Elevator machinery room, motor-generator set at left—Chickamauga.*

car, hoistway doors and frames, motor-generator set, and control equipment. Complete procurement specifications for the Kentucky elevator are included in appendix B.

OPERATING EQUIPMENT

Gearless-type machines are specified where considerable use is anticipated. They are also preferred over machines of the less expensive worm-gear type when noiseless operation, durability, and constant use are essential.

Gearless machines consist of a motor traction sheave and brake compactly grouped on a single shaft. Traction sheaves are semisteel or steel castings, or welded forgings and are thick enough to allow for regrooving, if worn. Sheaves have a diameter at least 40 times the diameter of the cable and are grooved for the cables. The sheave is integral with brake drum and bolted to the armature spider. Guards are furnished to prevent cables from jumping off the sheave in case of accident.

Geared hoisting machines consist of a worm-gear drive, with motor, brake, worm gearing, and driving sheave mounted on a single base or bedplate. Worms are accurately cut from solid steel forgings made integral with the worm shafts. The gears have solid bronze rims with machine-cut teeth. The worm gear and worm are enclosed in heavy cast-iron cases arranged to hold oil and with handholes for inspection. Oil seals at worm and worm-wheel shafts prevent oil leakage. Driving sheaves and worm wheels are mounted as a unit on a heavy forged-steel shaft. To take care of worm-gear thrust and prevent lateral movement of assembly on any change in direction of driving forces, the sheave is directly driven from the worm gear through a spider bolted to both worm gear and sheave, and sheave spiders are cast integrally with the connecting hub.

Guides for cars and counterweights are planed steel tee sections. Car guides weigh not less than 15 pounds per lineal foot and the

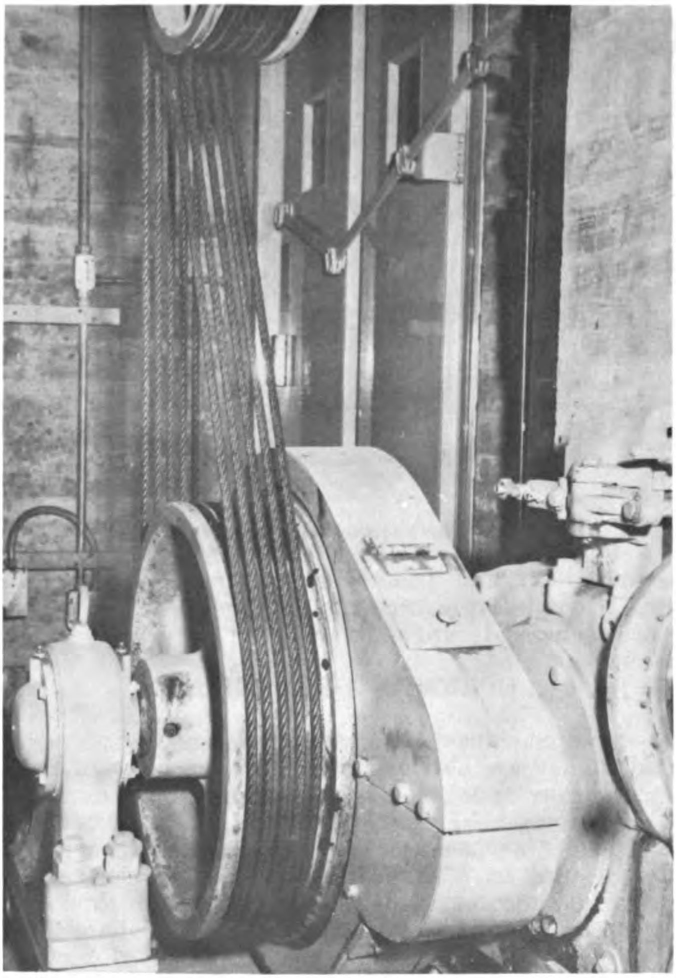


FIGURE 199.—*Basement drive elevator hoisting machine—Fontana.*

counterweight guides not less than 8 pounds per lineal foot. The guides are fastened in place with heavy clamps to brackets which are secured to the building structure.

All machines are provided with electromagnet-released, spring-set brakes, with two shoes independently actuated, secured to the motor frame or base, each having a spring of ample capacity to stop and hold the cars when carrying the maximum load. Figure 200 shows a typical brake arrangement. The springs are of the helical type, operated in compression, and apply the brake when released by the magnet. The brakes are designed for quick release, and the brake application is automatically controlled by magnetic retardation to obtain quiet, smooth, and gradual stops with either a light or heavily loaded car. Brake shoes are lined with fireproof friction material and run free with a minimum clearance.

A centrifugal governor equipped with an electric switch is provided for each car. The switch is specified to be operated by the

governor at not more than 120 percent of the rated car speed and to open motor and brake control circuits. If the opening of the above switch and application of the brake do not stop the car, or if for any other reason the speed of the car in the downward direction increases to 140 percent of the rated speed, the governor, in addition to opening the switch, locks the governor rope and sets the safety guide grips which stop the car. The governors are located so as to be protected from accidental injury and are provided with a metal cable guard.

Gearless machines are provided with cables of special traction steel consisting of not less than six strands each with hemp centers. Geared machines are provided with wire cable conforming to Federal Specification RR–R–571, Type XIV.

Elevators having high lifts are fitted with compensating chains on the cars to compensate for the varying weight of the hoisting cables due to the changing location of the cars in the hatchways. The chains are fastened to the bottom of the car frames and to the bottom of the counterweights, and are of such size and weight as to correspond to the weight of the hoisting cables.

Automatic adjustable lubricators are installed on the cars and counterweights for the lubrication of the guide rails. The lubricators are actuated by the car movement.

Counterweights are specified to be equal to approximately the weight of each complete car and 40 percent of the live load. They are made of solid cast-iron sections fitted to a frame.

Oil-cushioned buffers are specified for cars and counterweights where the car speed is 250 feet per minute and above. The buffers bring the cars and counterweights to a gradual stop at extreme limits of travel beyond terminal landings. The buffers absorb the weight of the moving parts and all the energy of car or counterbalance when traveling at 140 percent of the rated speed, with the average

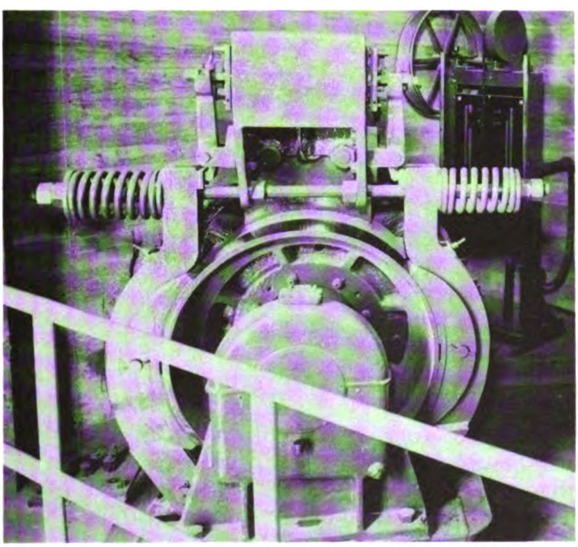


FIGURE 200.—*Elevator hoisting machine showing braking arrangement—Cherokee.*

retardation limited to 32.2 feet per second. Where spring buffers are installed, they are designed to absorb the energy of the car when traveling, fully loaded, at full speed. All buffers are mounted on suitable steel-bearing plates securely held in position.

ELEVATOR CARS AND DOORS

TVA specifies the approximate floor area for the car and permits the actual dimensions of the car to be the elevator manufacturer's standard, within the limits established by the available hatchway. A typical elevator car is shown in figure 201.

Car platforms consist of frames built of structural steel shapes securely riveted and bolted, or welded together. They are provided with vertical faces flush with the outer edges and extending a sufficient distance below the floor so there are no horizontal openings into the hoistways while the cars are within the landing zones and while the hoistway doors are wholly or partially open. The floors are wooden platforms securely bound with angle framing, mitered and welded at the corners. Platforms usually have spruce bases, fireproofed underneath with sheet iron, over which is placed a spruce nailing floor and a top layer of tongue and groove hard pine. The surface of the top layer is sanded to a smooth finish and covered with rubber tile over a layer of asphalt-saturated felt.

Passenger cars are usually constructed of polished furniture steel and the paneling reinforced with vertical stiffening angles Each car is equipped with an aluminum certificate frame and a manufacturer's nameplate on which the car loading capacity in pounds and number of passengers is stated.

Cars are provided with indirect lighting, handrailing, emergency exists, ventilation grilles, and telephones. They are equipped with hollow metal doors, reinforced for hangers, floor guides, closer arms and other hardware, and provided with sheave-type hangers for power operation. The doors are filled with cork or other sound-deadening material. Car doors are either of the single-leaf, single-

FIGURE 201.—*Elevator entrance and car—Chickamauga.*

speed type or of the 2-leaf, 2-speed design, depending upon the hatchway layout and the elevator service.

Hoistway doors are also of hollow metal construction and are designed to match the architecture at the various floor levels. The hollow metal hoistway doors for the Wheeler control building elevator are shown in figure 202.

Motor-driven electric operators are provided on most elevators to open and close the car door and hoistway doors when the car is at a landing. The car door and hoistway door at any landing are opened and closed simultaneously at a minimum speed of 1 foot per second without slam. An electromechanical interlock at each opening prevents the operation of the elevator unless all hoistway and car doors are closed and locked. An electric contact on the car door prevents the operation of the elevator unless all hoistway doors are closed and locked. An additional electric contact on the car door prevents the operation of the elevator unless the car door is closed. The door operators are so arranged that, in case of interruption or failure of electric power from any cause, the doors can be readily operated by hand from within the car. Emergency devices and keys for opening the doors from the landing are also provided as required by the local codes.

ELECTRICAL EQUIPMENT AND CONTROLS

The electrical system for direct-current operated elevators consists of a motor-generator and exciter set, hoist motor and brake, automatic push-button control, automatic 2-way leveling devices, automatic door operators, terminal and final limit switches, car lighting,

FIGURE 202.—*Elevator entrance doors—Wheeler control building.*

signal lights, and telephone. An individual motor-generator set is provided for each elevator, consisting of a 440-volt, 3-phase, 60-cycle motor driving a 230-volt direct-connected generator and exciter. A typical motor-generator set is shown at the left in figure 198. The set is an open-frame type with ample capacity for all operating and test conditions of the hoist motor. The motor and its controller are designed for across-the-line starting. Each hoist motor is a direct-connected, reversible, open-frame type, designed especially for elevator service for operation from the motor-generator set. Each motor is specified for continuous duty, 50-degree centigrade rise when in operation under full load conditions. The hoist motor control equipment is of the variable voltage or unit multivoltage type.

Elevators generally have selective collective automatic control. This control includes a series of push buttons in each car, numbered to correspond to the various landings, up-down push buttons and indicating light at intermediate landings, and single buttons and light at terminal landings.

Time limit relays are provided which for a predetermined period of time hold the cars at the landings where they have stopped before they will again start automatically in response to other calls. An emergency stop switch in each car interrupts the power supply and applies the brake independently of the regular operating devices. The motor-generator set automatically starts on the pressure of any of its car or landing buttons and continues to run for a predetermined time interval after the last call has been answered, when it automatically stops until another call is registered.

Each elevator is equipped with an automatic self-leveling device that brings the car to a position within ½ inch of the exact level with any floor for which either a car or landing button has been pressed. This self-leveling is entirely independent of the operating device and automatically corrects overtravel and undertravel of the car at each landing.

TVA furnishes and installs the main disconnect switches in the hoist machinery rooms, all embedded conduits with power conductors from the station service switchboard to the disconnect switches, all embedded conduits between the switches, the control panels, the motor-generator sets, and the hoist motors. The lighting and telephone conduits with conductors are also provided by TVA to junction boxes in the hatchways for extension by the contractor to the elevator cabs. The contractor furnishes and installs all exposed conduits and all conductors required for controls beyond the main switch and junction boxes listed above.

All conductors are installed in zinc-coated rigid steel conduit, except the flexible cable connections to the cars and such connections between controllers and other equipment which are self-supporting. All conduit fittings in the elevator pits are watertight. Separate cables and conduits are used for car lighting, control circuits, and telephones. Traveling cables are installed in such manner that there will be no strain on the electrical connections, and the ends of each cable are fastened to a terminal block having identifying numbers to facilitate tracing and replacement.

TESTING

TVA elevator specifications usually require the elevator contractor to make a drop test on each machine before the cables are permanently attached or the car superstructure has been installed. This test consists of cutting loose the car platform with a test load equal to the weight of the cab plus two-thirds of the contract load of the elevator. The total distance through which the car falls is specified to be not less than 6 feet nor more than 12 feet. At the end of the drop the car platform is not to be out of level more than one-half inch in each foot of distance between guide rails. Drop tests which have been conducted in accordance with the above specifications indicate that the car is seldom out of level more than one-sixteenth of an inch per foot. Measurements of slide after the safeties are tripped have always been within the code requirements.

In several cases TVA has permitted the substitution of a full load overspeed governor safety or runaway test in lieu of the drop test. This test is conducted after the car is completely installed and the permanent cables have been attached. Under this test the car is loaded to its rated capacity and the emergency stopping contact is shorted out on the governor. The car is overspeeded until the governor trips, setting the safeties on the car. Under these conditions the drive motor drum will slip through the cables, showing that the safeties are set solid on the car.

TVA waived all tests on a few elevators which were installed and placed in operation during the war emergency. In lieu of the usual tests, the elevator contractors were required to present evidence of approved drop tests which had been conducted in accordance with the codes on similarly rated machines having identical safety and governor equipment.

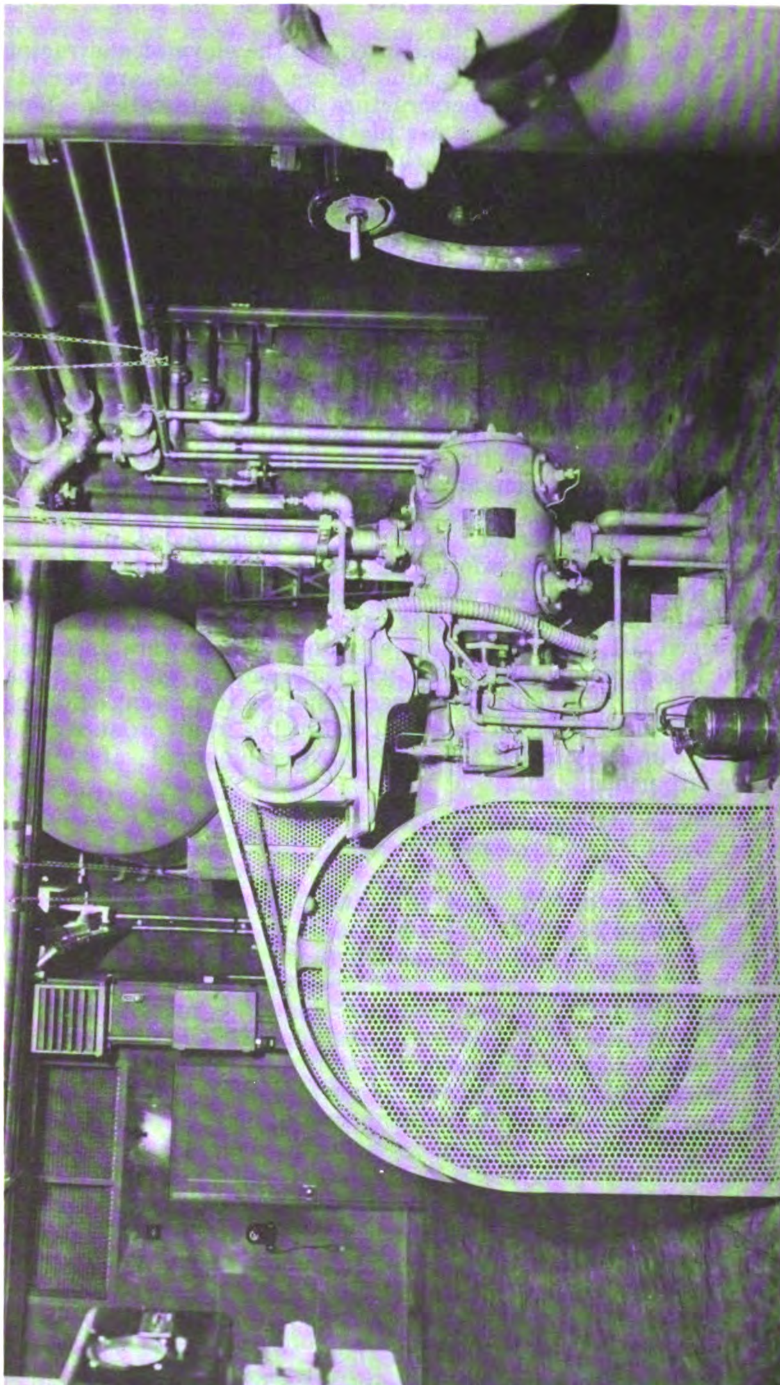


FIGURE 203.—*Typical 105-cubic-foot-per-minute station service air compressor—Chickamauga.*

CHAPTER 7

COMPRESSED AIR SYSTEMS

Compressed air is used in hydro plants in connection with various equipment and facilities which are supplied from appropriate air systems as shown in the following tabulation:

Use	*Air system*
Operation of pneumatically driven tools	Station air
Operation of pneumatically controlled valves	Station air
Operation of pneumatically operated ventilating dampers	Station air
Operation of hydropneumatic tanks	Station air
Operation of main generator brakes	Station air
Operation of turbine grease pump	Station air
Blowing out water intakes, drains, and coils	Station air
Draft tube evacuation	Evacuation air
Governor hydraulic system	Governor air
Ice prevention on spillway gates	Bubbler air
Elimination of vibration in unit structures	Vibration air

The above listed systems—as installed in TVA-built plants and unit additions to acquired plants—are discussed in this chapter.

Individual station air and governor air systems are installed in all plants with the exception of five unattended plants—Ocoee No. 3, Wilbur, South Holston, Chatuge, Nottely—where the two systems are combined. Automatic draft tube evacuation systems are installed in 10 plants—Wheeler, Pickwick, Guntersville, Chickamauga, Hiwassee, Watts Bar, Fort Loudoun, Kentucky, Fort Patrick Henry, Chatuge. Bubbler and vibration air systems are each installed in only one plant—the bubbler system at Kentucky and the vibration system at Guntersville—and in both cases are operated in conjunction with the evacuation air systems. Table 7 presents pertinent data covering the compressed air systems installed in each of the hydro plants.

DESIGN FEATURES

Certain features of design are observed in the layout of all compressed air systems; some of these are essential and others desirable. The compressor air intake is connected to outside air whenever possible. This is not always feasible in TVA plants. When it is not, the compressor is located in the lower levels of the substructure where the air is relatively cool and clean. All intakes are provided with combination air filters and silencers. A valve is never placed in the discharge line at the compressor without an intervening safety valve. Where water is used as the cooling medium for the compressor it is discharged through an open funnel so that it may be tested for temperature. It is important that the temperature of the discharge water be high enough to prevent condensate from forming

TABLE 7.—*Compressed air systems*

Project	Station air system							Governor air system		
	Stationary air system				Portable compressor			Compressor capacity		Motor (hp)
	Compressor capacity		Motor (hp)	Receiver storage (cubic feet)	Capacity		Motor (hp)	Cfm	Psi	
	Cfm	Psi			Cfm	Psi				
Norris	1 at 330 1 at 45	100	1 at 75 1 at 15	170				8	300	3
Wheeler	(c)							8	300	3
Pickwick	115	100	25	250	105	100	25	8.3	300	3
Guntersville	105	100	25	150	105	100	30	8	300	3
Chickamauga	105	100	25	150	105	100	25	8	300	3
Hiwassee	105	100	25	100	105	100	25	8	300	3
Watts Bar	119	100	25	150	108	100	25	8	300	3
Wilson 1–8	2 at 677	100	2 at 150	442	(e)			2 at 20±	200	2 at 5
Wilson 9–18 [d]								3 at 15.8	300	3 at 5
Cherokee	105	100	25	[d] 200	105	100	25	8	300	3
Douglas	105	100	25	[d] 200	105	100	25	8	300	3
Ocoee No. 3	(a)			84	105	100	25	8	300	3
Apalachia	105	100	25	103	85	100	25	8	300	3
Fort Loudoun	113	100	25	150	93	100	25	8	300	3
Kentucky	113	100	25	150	82	100	25	8	300	5
Fontana	1 at 300 1 at 111	100	1 at 75 1 at 25	[d] 200	105	100	25	8	300	5
Watauga	61	100	15	50	105	100	25	8.3	300	3
Wilbur 4	(a)			38				8.3	300	3
South Holston	(a)			100	94	100	25	20.5	300	7.5
Hales Bar 15 and 16	(c) 766	100	150	100	100	100	25	9.4	300	3
Boone	111.5	100	25	[d] 200	105	100	25	9.4	300	3
Fort Patrick Henry	111.4	100	25	50	105	100	30	9.4	300	3
Chatuge	(a)			50	105	100	25	20.8	300	7.5
Nottely	(a)			50				20.8	300	7.5

Project	Draft tube evacuation air system: Compressor capacity, Cfm	Draft tube evacuation air system: Compressor capacity, Psi	Draft tube evacuation air system: Motor (hp)	Draft tube evacuation air system: Air receiver storage (cubic feet)	Draft tube evacuation air system: Volume of displaced water (cubic feet)	Draft tube evacuation air system: Resulting pressure at normal tailwater (psi)	Lock air system: Compressor capacity, Cfm	Lock air system: Compressor capacity, Psi	Lock air system: motor (hp)	Lock air system: Air receiver storage (cubic feet)
Norris										
Wheeler	2 at 330 1 at 95	100	2 at 100 1 at 25	3,000	6,020	7	25	100	5	40
Pickwick	472	100	100	3,500	12,530	11	[f] 40	400	20	105
Guntersville	[b] 472	100	100	2,700	8,110	7	60	110	10	41
Chickamauga	472	100	100	2,520	8,110	10	60	110	10	41
Hiwassee	1 at 284 1 at 546	100	1 at 75 1 at 100	1,050	Unit 1, 1,450 Unit 2, 3,710	Unit 1, 5 Unit 2, 9				
Watts Bar	331	100	75	2,000	6,830	10	60	100	15	45
Wilson 1-8										
Wilson 9-18 [d]										
Cherokee										
Douglas										
Ocoee No. 3										
Apalachia										
Fort Loudoun	343	100	75	2,000	5,360	9	60	100	15	41
Kentucky	343	100	75	3,000	9,650	10	60	100	15	45
Fontana										
Watauga										
Wilbur 4										
South Holston										
Hales Bar 15 and 16										
Boone										
Fort Patrick Henry	342	100	75	1,050		7				
Chatuge	115	100	25	200	500	4				
Nottely										

[a] Station air system supplied by governor air compressor.
[b] This compressor also furnishes air for the control of unit vibration.
[c] Station air compressor serves 16 hydro units and steam plant.
[d] Manual draft tube depression by valved air line to head cover.
[e] Same compressors serve evacuation and station air systems.
[f] Serves hydropneumatic accumulator for lock gate oil system.
[g] No portable unit at the plant but in any emergency one may be obtained from the nearby Power Service Building.

in the air inlet passages of the cylinder. If condensate forms, it might be carried into the air cylinder, destroying the lubricant, thus causing excessive cylinder wear.

A water-cooled aftercooler is always used after single-stage compression to remove excess moisture in the air to prevent its condensing in the distribution system. Another purpose of the aftercooler is to remove lubricating oil vapor which, under abnormal operating conditions, presents an explosion hazard. An air-through-the-tubes type aftercooler with moisture-oil separator at the discharge end is installed between the compressor and receiver. A small amount of moisture and oil is still carried over to the receiver and distribution system and must be removed by traps or manually operated blowoff accumulators. Traps or accumulators are placed at low points in the line so that they have gravity drainage to them. All branch lines are taken from the top of the main lines to reduce the amount of condensate at terminal valves and to minimize the number of traps.

An air receiver is an essential part of a reciprocating air compressor installation—all TVA installations are this type. It serves to dampen the pulsating effect of the compressor, serves as an equalizer and reservoir of power, and further cools the air, causing it to deposit a part of its moisture in the receiver where it is removed by a blowoff or trap. The inlet and outlet pipes of the receiver are placed in proper relative position to prevent air from passing out before it has cooled sufficiently to drop much of its entrained moisture. The compressor or aftercooler discharge is normally connected to a point near the top of the receiver, and the receiver outlet is connected at right angles to a lower point. Damage resulting from a ruptured receiver is likely to be severe. For this reason TVA specifies that the tank shall be built in accordance with the ASME Code for Unfired Pressure Vessels.

STATION AIR SYSTEM

Pneumatic tools operate most efficiently using air at pressures of 80 to 100 pounds per square inch and, since the other uses for compressed air require pressures less than this, 100 pounds per square inch has been adopted as a standard pressure for all air compressors serving the station air systems. One stationary compressor having a capacity of approximately 105 cubic feet per minute has been found to be adequate for the normal requirements at most plants. Figure 203 shows a typical station air compressor of 105-cubic-foot-per-minute capacity installed at the Chickamauga project. A typical diagram of a station service compressed air system is shown in plate 15.

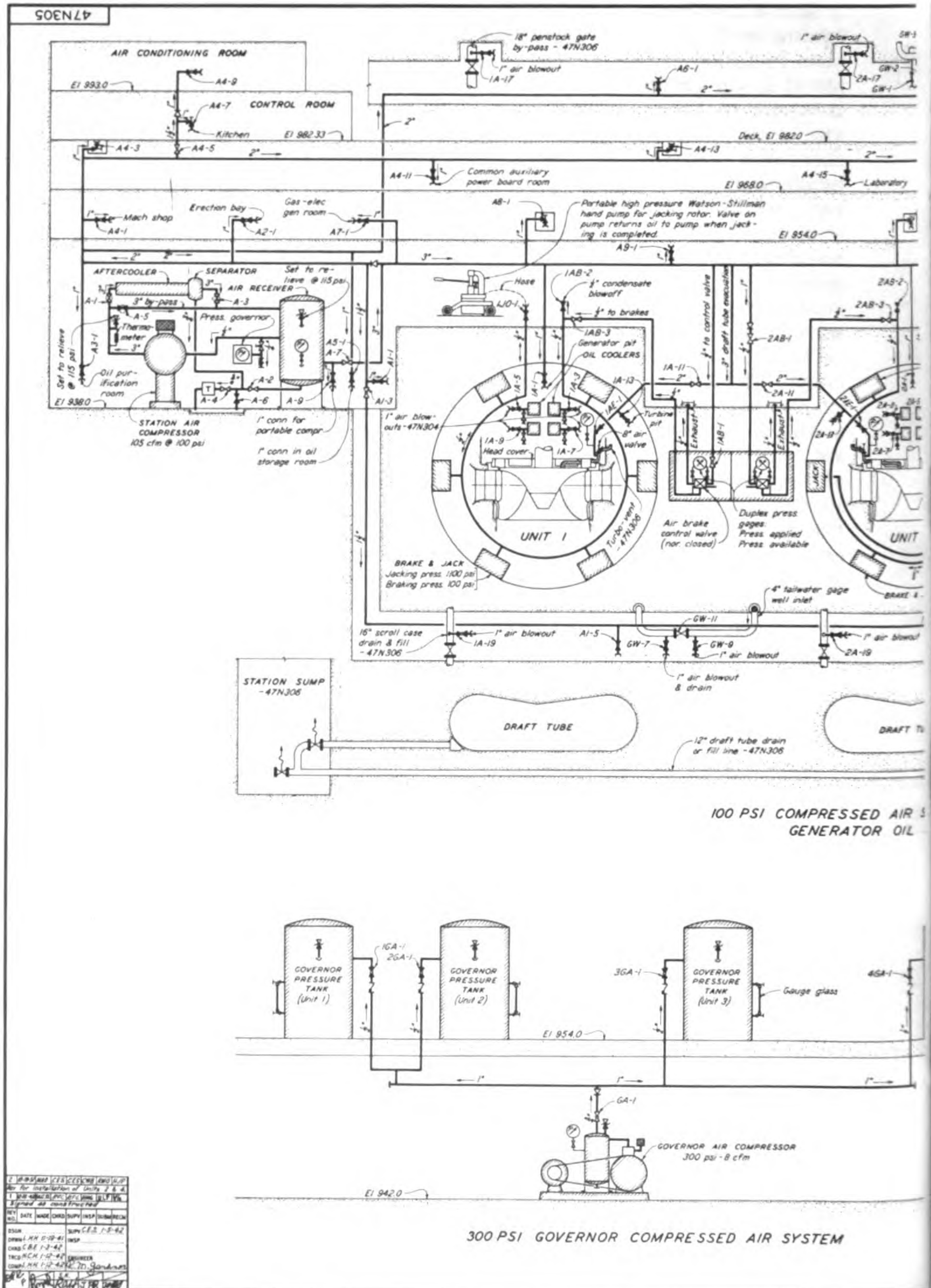
A complete piping system distributes the air to various service outlets throughout the powerhouse and usually on the draft tube and intake decks. The latter outlets are mainly for gate servicing and painting. Service outlet valves, which are 1-inch size of the globe or angle type, are installed in cabinets along with water service valves or exposed along the walls of galleries. Universal couplings with caps and chains are fitted to the service valves for attachment of air hose. Three 25-foot lengths of 1-inch-diameter rubber air hose with universal type couplings are usually provided at each project for general air use.

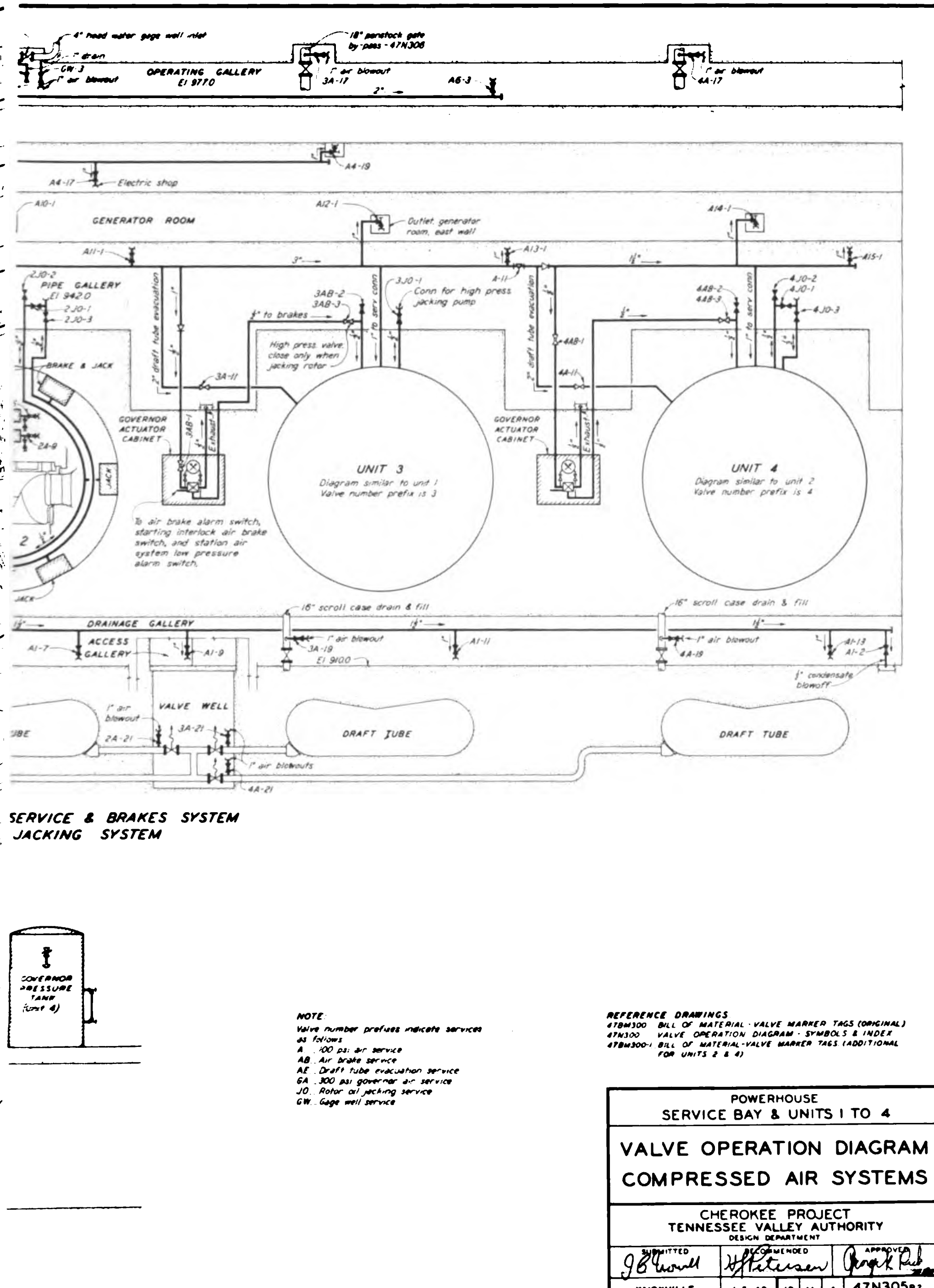
Air is usually supplied to the generator brakes at 100 pounds per square inch, but in a few instances a pressure reducing valve has been installed at the request of the generator manufacturer to supply air at lower pressures. The customary air brake system consists of a U-type pipe header connected to four or more combination air brake and rotor jack cylinders located within the generator underneath the rotor. Figure 245 of chapter 10 illustrates a combination air brake and rotor jacking system. The air supply for each generating unit, which is connected to one end of the U-header, is controlled by a motorman-type valve in the governor cabinet. At plants which are not remotely controlled this valve is manually operated at the governor cabinet. At remotely controlled plants an automatic brake control mechanism is provided which will apply the brakes intermittently when the unit is shut down. This mechanism is adjustable as to delay before application and number of intermittent applications. It is also possible to operate the brake control valve manually at remotely controlled plants. Each brake control valve is provided with 3 pressure switches—1 to indicate application of brakes, 1 to prevent starting with brakes applied, and 1 to alarm on low station air pressure. A duplex pressure gage for indicating the pressure in the station air supply and in the brake cylinder is mounted on the governor cabinet. An exhaust line from each valve is run to a convenient gutter. The same cylinders used for braking are used as oil jacks for lifting the rotating elements of the generator and turbine for inspection and removal of bearing parts. Mechanical blocks attached to the jacks hold the rotor in the raised position. The oil is supplied to the other end of the U-header by a portable, hand-operated, high-pressure oil pump furnished by the generator contractor. A header returns leakage oil from the jacks to a receptacle in the pipe gallery. Provision is also made to drain the air brakes U-header to this receptacle.

Compressed air for operation of ventilating damper motors and controls and for loading pressures on the diaphragms of pneumatically controlled valves is usually reduced to 15 or 20 pounds per square inch by individual pressure regulators. Control air must be clean and free from oil. Several types of air filters have been utilized for this purpose. Air at 100 pounds per square inch is supplied to air-operated grease pumps which are installed in some plants for lubrication of the turbines. These pumps supply grease to the turbine wicket gates and other moving parts at pressures ranging from 3,000 to 4,000 pounds per squire inch.

Certain major raw water intake pipelines and the scroll case and draft tube drains are provided with 1-inch valves and hose couplings to which air hose may be attached for blowing out or clearing debris from inlet or drain gratings. Water cooling coils in the main generator bearing oil reservoirs are also fitted with similar blowout connections.

At Chickamauga and Guntersville projects, compressed air is used to boost the pressure of the raw water fire and service system. This is effected by maintaining compressed air at a predetermined pressure in a hydropneumatic tank which is supplied water by the raw water fire and service pumps. Station air pressure is reduced by reducing valves to 90 pounds per square inch at Chickamauga


47N305
AIR CONDITIONING ROOM
CONTROL ROOM
Kitchen
Mach shop
Erection bay
Gas-elec gen room
AFTERCOOLER
SEPARATOR
AIR RECEIVER
Set to relieve @ 115 psi
Press. governor
Thermometer
Oil purification room
STATION AIR COMPRESSOR 105 cfm @ 100 psi
1" conn for portable compr
1" conn in oil storage room
18" penstock gate by-pass - 47N306
Common auxiliary power board room
Portable high pressure Watson-Stillman hand pump for jacking rotor. Valve on pump returns oil to pump when jacking is completed.
Laboratory
Generator pit OIL COOLERS
Head cover
Turbine pit
8" air valve
Turbo-vent -47N306
UNIT 1
BRAKE & JACK Jacking press. 1100 psi Braking press. 100 psi
Air brake control valve (nor. closed)
Duplex press gages: Press. applied Press. available
4" tailwater gage well inlet
16" scroll case drain & fill - 47N306
1" air blowout & drain
STATION SUMP -47N306
DRAFT TUBE
12" draft tube drain or fill line -47N306
100 PSI COMPRESSED AIR
GENERATOR OIL
GOVERNOR PRESSURE TANK (Unit 1)
GOVERNOR PRESSURE TANK (Unit 2)
GOVERNOR PRESSURE TANK (Unit 3)
Gauge glass
GOVERNOR AIR COMPRESSOR 300 psi - 8 cfm
300 PSI GOVERNOR COMPRESSED AIR SYSTEM


4" head water gage well inlet
1" drain
GW-3
1" air blowout
OPERATING GALLERY
El 977.0
18" penstock gate by-pass - 47N306
1" air blowout
3A-17
A6-3
2"
1" air blowout
4A-17
A4-19
A4-17
Electric shop
A10-1
GENERATOR ROOM
A12-1
Outlet generator room, east wall
A14-1
A11-1
3"
A13-1
A15-1
2J0-2
PIPE GALLERY
El 942.0
2J0-1
2J0-3
2" draft tube evacuation
3AB-2
3AB-3
1/2" to brakes
3J0-1
Conn for high press jacking pump
1" to serv conn
High press valve, close only when jacking rotor
A-11
4AB-2
4AB-3
4J0-2
4J0-1
4J0-3
4AB-1
2" draft tube evacuation
4A-11
BRAKE & JACK
3A-11
GOVERNOR ACTUATOR CABINET
3AB-1
Exhaust
24-9
JACK
UNIT 3
Diagram similar to unit 1
Valve number prefix is 3
UNIT 4
Diagram similar to unit 2
Valve number prefix is 4
To air brake alarm switch, starting interlock air brake switch, and station air system low pressure alarm switch.
16" scroll case drain & fill
DRAINAGE GALLERY
ACCESS GALLERY
A1-7
A1-9
1" air blowout
3A-19
El 910.0
A1-11
4A-19
A1-13
A1-2
1/2" condensate blowoff
1" air blowout
VALVE WELL
2A-21
3A-21
DRAFT TUBE
1" air blowouts
4A-21
SERVICE & BRAKES SYSTEM
JACKING SYSTEM
GOVERNOR PRESSURE TANK (unit 4)
NOTE:
Valve number prefixes indicate services as follows:
A . 100 psi air service
AB . Air brake service
AE . Draft tube evacuation service
GA . 300 psi governor air service
JO . Rotor oil jacking service
GW . Gage well service
REFERENCE DRAWINGS
47BM300 BILL OF MATERIAL - VALVE MARKER TAGS (ORIGINAL)
47N300 VALVE OPERATION DIAGRAM - SYMBOLS & INDEX
47BM300-1 BILL OF MATERIAL - VALVE MARKER TAGS (ADDITIONAL FOR UNITS 2 & 4)
POWERHOUSE
SERVICE BAY & UNITS 1 TO 4
VALVE OPERATION DIAGRAM
COMPRESSED AIR SYSTEMS
CHEROKEE PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
1-5-42
12
M
4
47N305R2

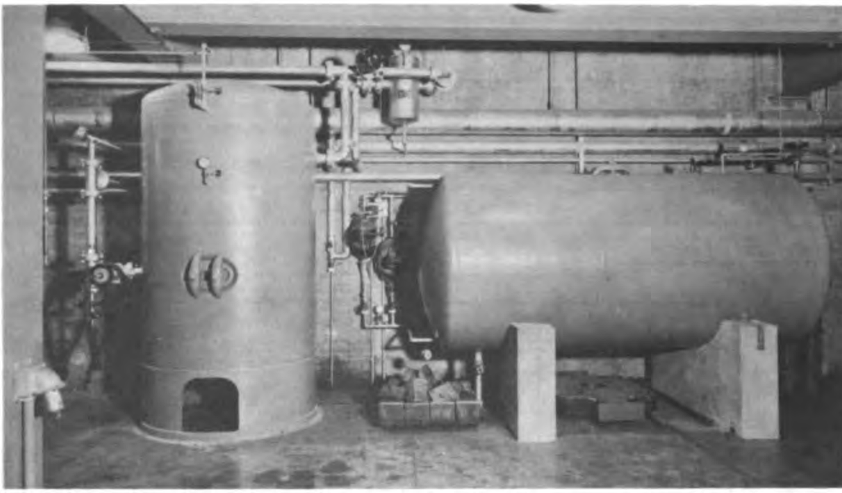


FIGURE 204.—*Station service air receiver at left and hydropneumatic fire and service water storage tank at right—Chickamauga.*

and 82 pounds per square inch at Guntersville. Figure 204 shows the station service air receiver and hydropneumatic tank at the Chickamauga project. Float switches control the operation of the two raw water fire and service pumps at each plant in order to maintain a constant air-water level in the tank. Each of these two plants has a forging furnace which uses compressed air in its operation. The station air system furnishes air which is reduced in pressure to that required for the transfer of oil to the burners and for atomizing of oil in the burners.

The built-in station air system is supplemented at most projects by a portable compressor which is used when major repair work requires additional air capacity. This unit is generally a 105-cubic-foot-per-minute machine operating at 100-pound-per-square-inch pressure. Electrical outlets are provided throughout the plant area, making it possible to use the compressor either in isolated locations, such as the roadway crossing the dam, in the switchyard, or in the powerhouse to supplement the stationary machine.

NAVIGATION LOCK AIR SERVICE

On dams with navigation locks—main river projects only—compressed air is used in the lock for tool service and for operation of the communication horn used by the lock operators to signal and control traffic through the lock. The air supply is normally furnished by a stationary, 2-stage, air-cooled, single acting, electric-motor-driven, direct-connected air compressor rated at 60 cubic feet of free air per minute discharging at 100-pound-per-square-inch pressure. Figure 205 shows a typical lock air compressor and receiver. Receiver capacities vary between 40 and 45 cubic feet. The compressor and receiver are normally located in the basement of the lock operations building. A complete piping system distributes the air to the various service outlets throughout the lock and to the signal horn.

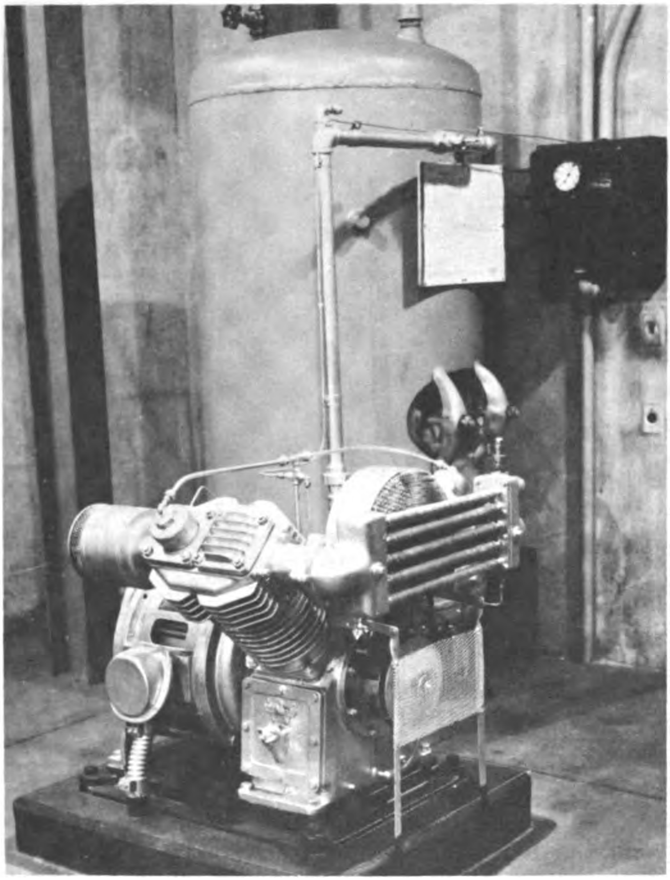


FIGURE 205.—*Typical air-cooled lock air compressor with receiver—Fort Loudoun.*

EVACUATION AIR SYSTEM

The draft tube evacuation air system depresses the water level in the draft tube below the bottom of the turbine runner when it is desired to motor the unit. This is done to save power when a unit is operating as a synchronous condenser to regulate voltage and correct power factor. Figure 206 shows a typical schematic control diagram for this type of air system. At the Hiwassee unit 2 pump-turbine the water in the draft tube must also be depressed when the pumping operation is started or stopped. This allows the unit to be brought up to speed at part voltage before adding load and to drop off gradually in stopping.

For draft tube evacuation a separate air system with compressors ranging in size from 100 to 550 cubic feet per minute operating at a discharge pressure of 100 pounds per square inch and with air storage varying from 200 to 3,500 cubic feet, depending upon the volume of water to be displaced in the draft tubes at each plant, is provided. Figure 207 shows a 331-cubic-foot-per-minute air com-

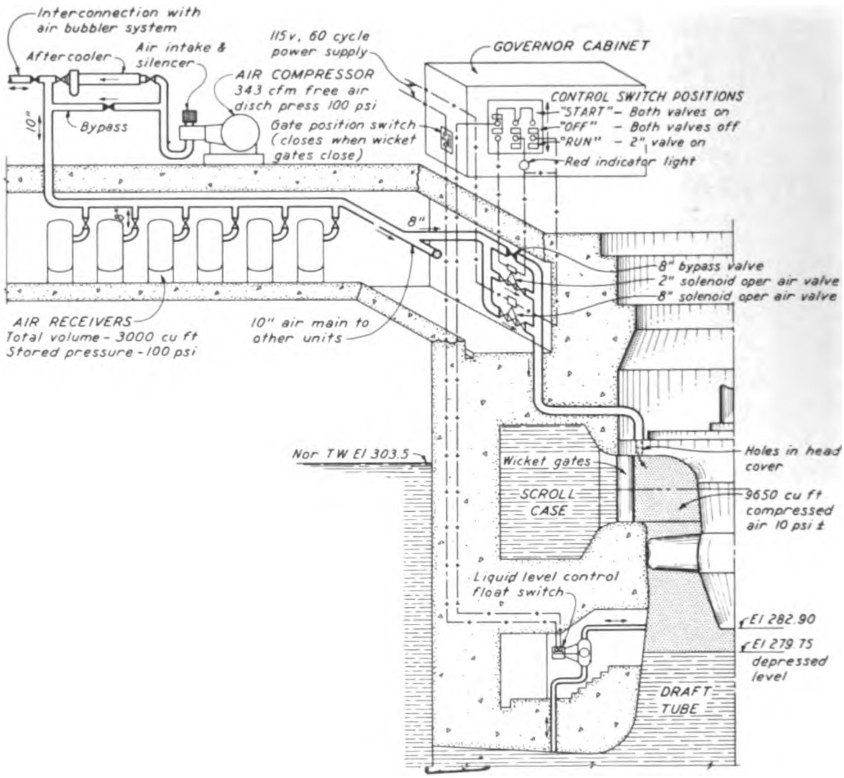


FIGURE 206.—*Schematic control diagram of draft tube evacuation air system—Kentucky.*

pressor and the four 500-cubic-foot air receivers installed at Fort Loudoun for draft tube evacuation. A complete piping system carries the air from the storage receivers to the head covers of the turbines. Two solenoid-operated valves, one 4- to 8-inch size and one 2-inch size, arranged in parallel, are located adjacent to the unit in the air supply to each head cover. Operating air for the valves is piped from the station air receiver. In a station that is not remotely controlled one cage-type float control is attached to each draft tube liner adjacent to the draft tube access door, and a selector switch for control of the system is mounted on the governor actuator panel.

Typical operation for the evacuation air system is as follows. With the unit on load, when the control room operator wishes to operate the generator as a synchronous condenser he telephones the governor attendant, who sets the control switch to the "Start" position which energizes the solenoids of both the large and small control valves. The switchboard operator then backs off his load, and when the wicket gates have reached the fully closed position, the electrical circuit is completed through a contact on the gate position switch which allows both the large and small solenoid-operated valves (see figures 208 and 209) to open fully and release compressed air into the draft tube. When sufficient air has been released into the draft

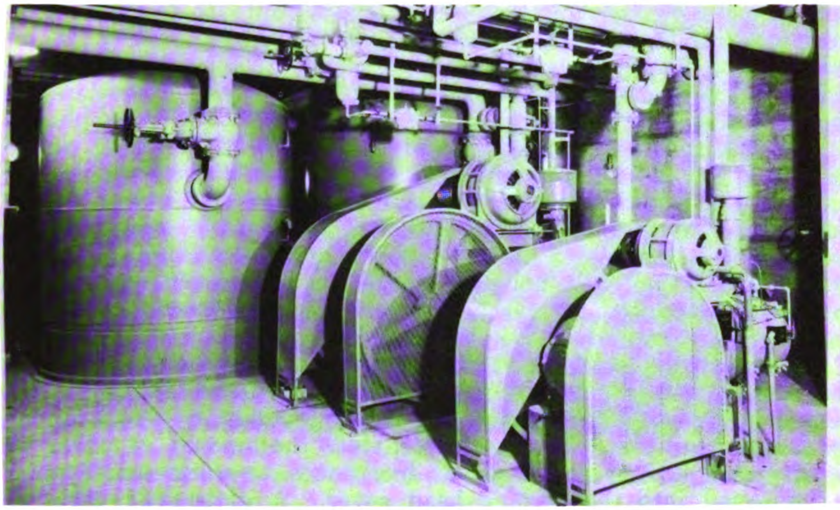


FIGURE 207.—*Evacuation and station air system compressors, evacuation air receivers at rear—Fort Loudoun.*

tube to depress the water down to the level of the float switch, it opens to shut off the air valves. The governor attendant then sets the control switch to the "Run" position which permits only the 2-inch valve to operate under the regulation of the float control to compensate for any leakage loss from the draft tube and to maintain the depressed level below the runner. A red signal light on the governor cabinet appears each time the air valves open to signal the operator that air is being admitted to the draft tube. To restore the unit to normal operation as a generator, it is only necessary to open the wicket gates and set the control switch to the "Off" position which will shut off the air supply. One wire of the electrical control circuit is carried through the wicket gate position switch to prevent operation of this system if the wicket gates are open. Air is forced out of the draft tube to the tailrace as the wicket gates open and headwater enters.

In an unattended or remotely controlled station the operation of the system is much simpler. Instead of 1 float switch controlling both solenoid-operated air valves, 2 float switches are provided. The first float switch below the runner controls the large air valve. The other float switch, located 12 to 18 inches lower, controls the small air valve which compensates for leakage loss. The arrangement is such that when the wicket gates are closed the system automatically operates unless the generator breaker is opened and the unit disconnected from the electrical distribution system. If for any reason generation is required, the opening of the wicket gates will deenergize the control valves and shut off the supply of air. Suitable electrical interlocks, in the form of speed switch and an "Off-On" switch located on the governor cabinet, are provided to prevent the accidental operation of the system.

With tailwater at normal elevation, air pressure in the draft tube during evacuation does not exceed 10 pounds per square inch in most plants. The usual time to motor a unit with compressed air is

approximately 1 minute, with the kilowatt input to the generator ranging from 600 to 800, depending upon the blade tilt and size of the runner. Motoring without the injection of compressed air requires in the neighborhood of 3,500 to 5,000 kilowatts, again depending upon the size of the runner and the position of the runner blades.

Automatic evacuation facilities similar to those described above have been installed in ten plants to date. Five of these are remotely controlled stations—Fort Patrick Henry, Chatuge, Hiwassee, Chickamauga, and Guntersville. Estimates and preliminary design studies have also been completed for the remote control of Wilson units 9–18 and Apalachia units 1 and 2. Provisions were made for future installation of automatic evacuation facilities at Hales Bar units 15 and 16, which are also remotely controlled.

At several plants where Francis turbines are installed and where the runner settings are very close to normal tailwater level, provisions are made to manually depress tailwater for synchronous condenser operation. In these cases, since the amount of water to be displaced is very small, an air line from the station air system is connected into the turbine head cover. A globe-type valve is provided for the manual admission of air. It is necessary to increase the capacity of the station air receiver by the amount required for evacuation.

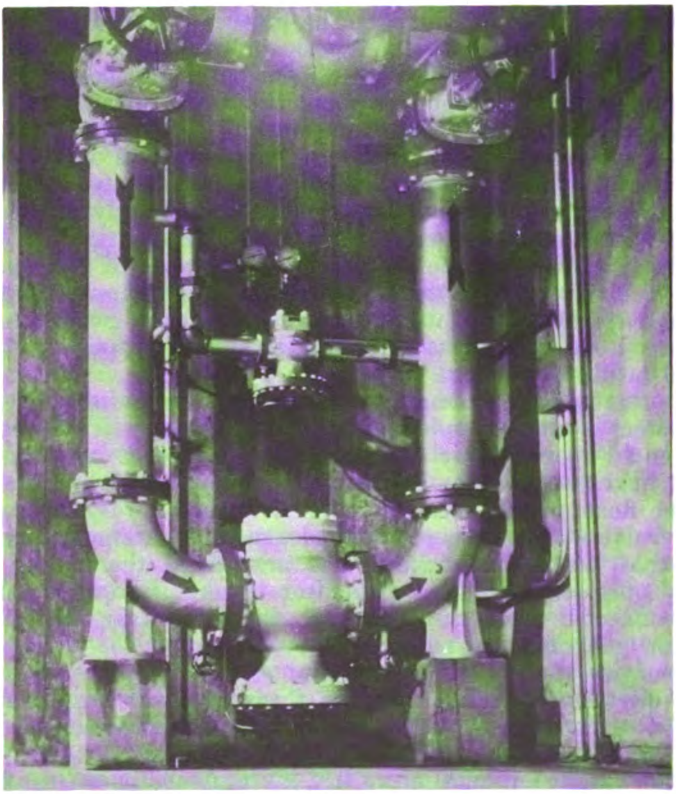


FIGURE 208.—*8- and 2-inch solenoid-operated draft tube evacuation air valves—Wheeler*

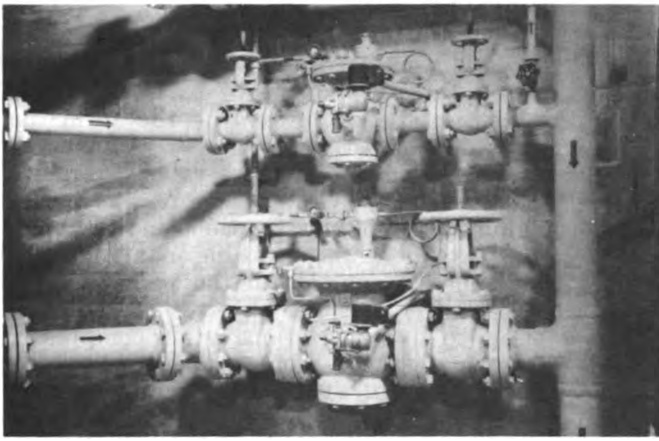


FIGURE 209.—*4- and 2-inch draft tube evacuation air valves—Chatuge.*

After Hiwassee unit 1 was converted for remote control, trouble was experienced in the operation of the automatic draft tube evacuation air system. The 284-cubic-foot-per-minute compressor operated excessively—about 75 percent of the time—while the unit was condensing. The reason for this was believed to be that lubricating water from the upper runner seal was flowing down the draft tube liner into the upper control pipe to the float switches, preventing control piping from draining properly and causing the float switches to close when they should not. This condition was remedied by running a ½-inch pipe from the evacuation air supply line following the 2-inch control valve to a tee inserted in the upper control pipe to the float switches. A throttling valve was placed in the purging line.

At Chatuge this feature was incorporated into the original design of the draft tube evacuation air system. The only difference was that at Chatuge the purging line was connected to the upper float control line farther from the float switches toward the draft tube liner. During operation, however, results were similar to those first experienced at Hiwassee unit 1—continuous operation of the compressor while condensing. This suggested the possibilities that purging air was being admitted at the wrong point on the float control line, or that it was being admitted at the wrong time since it was being supplied from the outlet side of the small control valve, or that it was not being supplied in sufficient quantity. As a solution, it has been proposed that the purging air line be run from the draft tube evacuation air receiver to a point in the float control line near the upper float switch with a solenoid-operated valve in the purging line to open when the unit starts condensing and to close when it stops condensing. A manual throttling valve would also be placed in the purging line, to be tested for correct opening during evacuation. As yet these proposed changes have not been made, but it is expected that they will remedy the situation.

BUBBLER AIR SYSTEM

A separate compressed air system, known as the spillway bubbler air system, was installed at one plant only—Kentucky. This system was installed for the purpose of preventing the formation of ice on the spillway gates during periods of severe winter weather. It is necessary to maintain control of the reservoir storage capacity and water level at all times, and various combinations of gates may be required to operate. Design investigations indicated that 12 of the 24 spillway gates would be the probable maximum number required to operate during that portion of the winter when freezing temperatures are expected.

The system is supplied by one stationary air compressor having a capacity of 343 cubic feet per minute, operating at a pressure of 100 pounds per square inch. This compressor is a duplicate of the draft tube evacuation air compressor, and the two systems are interconnected to provide standby capacity for each other. A flow diagram of these systems is shown in plate 16. The compressor and a 500-cubic-foot air receiver are located in the powerhouse service bay. A complete piping system carries the air from the receiver through a pressure reducing station to twenty-four valved outlets located in boxes on the spillway deck (see plate 1, page 177). Each box contains a throttling needle valve, a strainer, a pressure gage, and two ½-inch hose connections. In addition, beginning with the second box, every fourth box has a 1-inch valved outlet for general air service.

It was assumed that one hose length per bay would be sufficient for short periods of freezing weather, but that two lengths might be required for long periods of more severe weather. One end of the ½-inch armored hose is attached to the connection in the box. The other end of the hose is submerged in about 10 feet of water on the reservoir side of the gate. The submerged end of the hose is fitted with an orifice nozzle. An 8-pound lead casting attached to the nozzle serves to hold the hose in position. The hose lengths are stored when not in use.

Experiments conducted in connection with a similar system at Grand Coulee Dam indicated that reservoir water temperatures at depths of more than 8 feet were relatively constant and that surface ice produced very little change in temperature. Compressed air discharging under water is utilized to produce an upward flow of the warm water to prevent the formation of surface ice. Experiments were also made using compressed air discharging through orifices, the final results of which indicated that a sharp-edged orifice of ⅛-inch diameter and a tube length of three diameters gave the best bubble pattern to produce the required upward mixing flow. The pressure reducing station reduces the receiver pressure to 25 pounds per square inch.

Two bypass arrangements are provided—one to throttle the bubbler air supply if the pressure reducing valve should fail, and the other to provide 100-pound-per-square-inch air to the deck for general service. Should general air service be required on the

spillway deck during periods of bubbler operation, the portable air compressor would be used. Air supplied to the orifice is throttled to approximately 6 pounds per square inch by the needle valve at the box.

GOVERNOR AIR SYSTEM

Compressed air for the governor system, which is independent of all other air systems in most plants, is supplied by a compressor furnished by the governor contractor at each plant. These are usually compressors of the stationary type, ranging in capacities from 8 to 20 cubic feet per minute at a discharge pressure of 300 pounds per square inch, and with a small air receiver. In some of the earlier designs a portable compressor was provided which was moved at intervals to several governor pressure tanks in a station for pumping up the initial pressure in the system. The frequency of moving the compressor and making flexible connections to the pressure tanks proved to be a cumbersome and unnecessary operation.

In the more recently designed plants the governor air compressor is of the stationary type and is usually installed in the pipe gallery near the units. A permanent piping system is connected from the compressor to each of the governor pressure tanks. Figure 210 shows a typical flow diagram of the governor air system. Pressure in the compressor receiver is automatically maintained by a pressure switch which stops and starts the compressor motor. Air is bled into the governor pressure tanks, as required, by operation of a manual control valve at each tank. After the tanks are filled with air, the system pressure is maintained by the governor oil pumps. A typical governor air compressor is shown in figure 211.

At the Wilson project three governor air compressors are provided for units 9 through 18. It was considered desirable at this plant to have standby compressor capacity for these ten generating units. Stationary compressors are mounted inside the twin governor cabinets of units 11 and 12, 13 and 14, 15 and 16. These compressors are connected into a single pipe main which supplies all units.

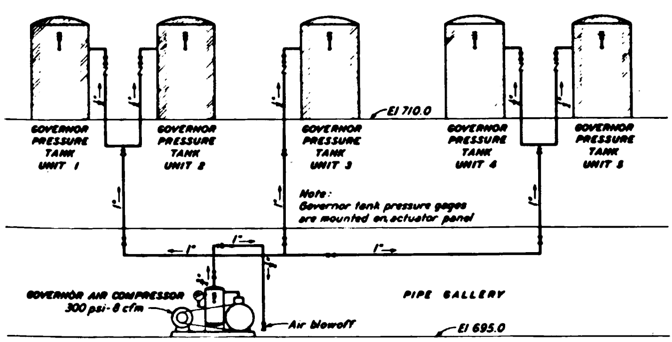
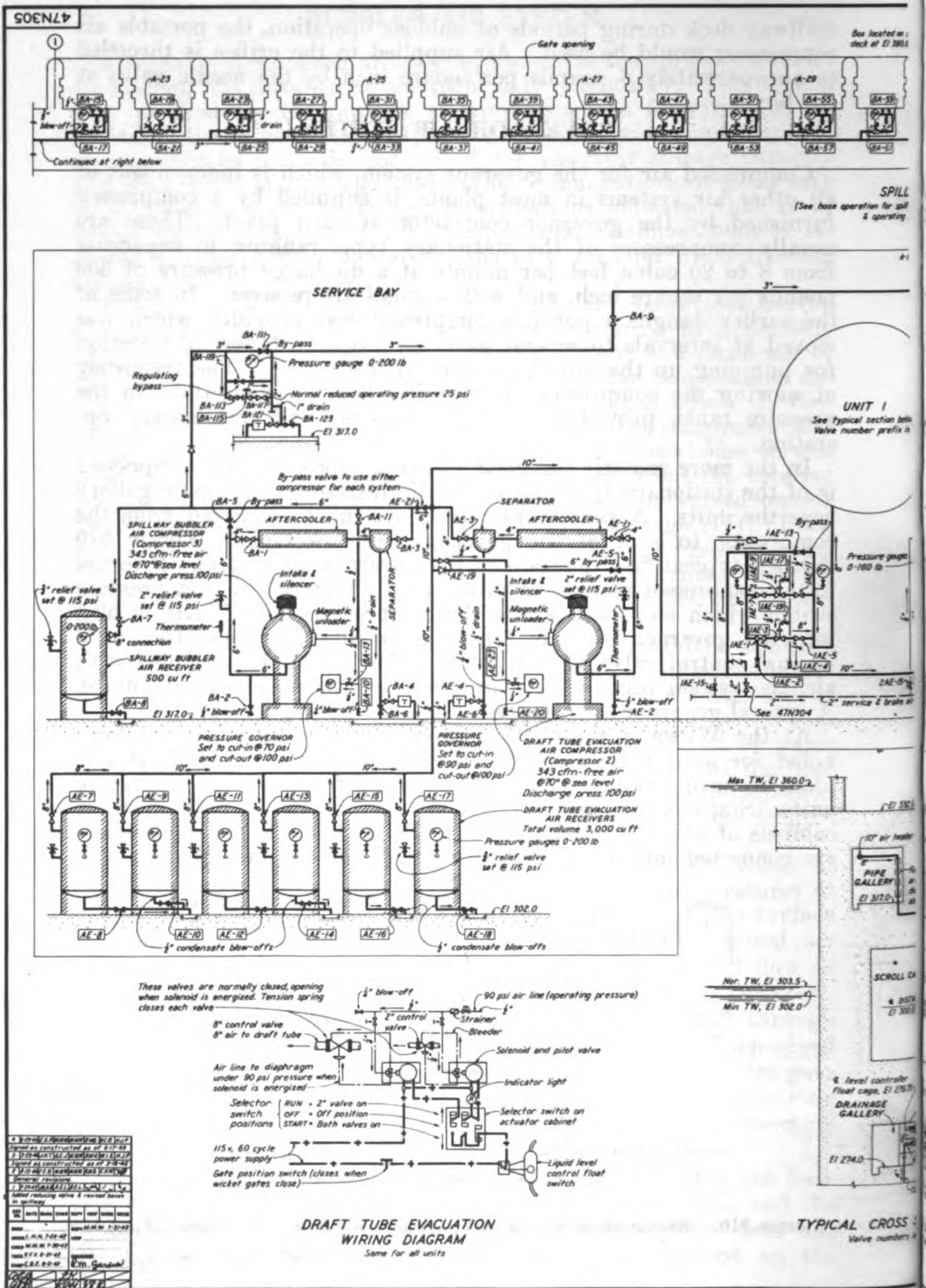


FIGURE 210.—*300-pound-per-square-inch governor compressed air system—Watts Bar.*


47N305
Gate opening
Continued at right below
SPILL
SERVICE BAY
By-pass
Pressure gauge 0-200 lb
Regulating bypass
Normal reduced operating pressure 25 psi
1" drain
El 317.0
By-pass valve to use either compressor for each system
SEPARATOR
AFTERCOOLER
AFTERCOOLER
SPILLWAY BUBBLER AIR COMPRESSOR (Compressor 3) 343 cfm-free air @70° @sea level Discharge press.100psi
Intake & silencer
Magnetic unloader
Thermometer
2" relief valve set @ 115 psi
SPILLWAY BUBBLER AIR RECEIVER 500 cu ft
El 312.0
PRESSURE GOVERNOR Set to cut-in @70 psi and cut-out @100 psi
PRESSURE GOVERNOR Set to cut-in @90 psi and cut-out @100 psi
DRAFT TUBE EVACUATION AIR COMPRESSOR (Compressor 2) 343 cfm-free air @70° @ sea level Discharge press 100psi
DRAFT TUBE EVACUATION AIR RECEIVERS Total volume 3,000 cu ft
Pressure gauges 0-200 lb
relief valve set @ 115 psi
El 302.0
condensate blow-offs
UNIT 1
Pressure gauge 0-160 lb
2" service & brake air
See 47N304
Max TW, El 360.0
PIPE GALLERY
Nor. TW, El 303.5
Min TW, El 302.0
SCROLL CASE
DRAINAGE GALLERY
El 274.0
These valves are normally closed, opening when solenoid is energized. Tension spring closes each valve
8" control valve
8" air to draft tube
2" control valve
90 psi air line (operating pressure)
Strainer
Bleeder
Solenoid and pilot valve
Air line to diaphragm under 90 psi pressure when solenoid is energized
Indicator light
Selector switch positions
RUN - 2" valve on
OFF - Off position
START - Both valves on
Selector switch on actuator cabinet
115v, 60 cycle power supply
Gate position switch (closes when wicket gates close)
Liquid level control float switch
DRAFT TUBE EVACUATION WIRING DIAGRAM
Same for all units
TYPICAL CROSS

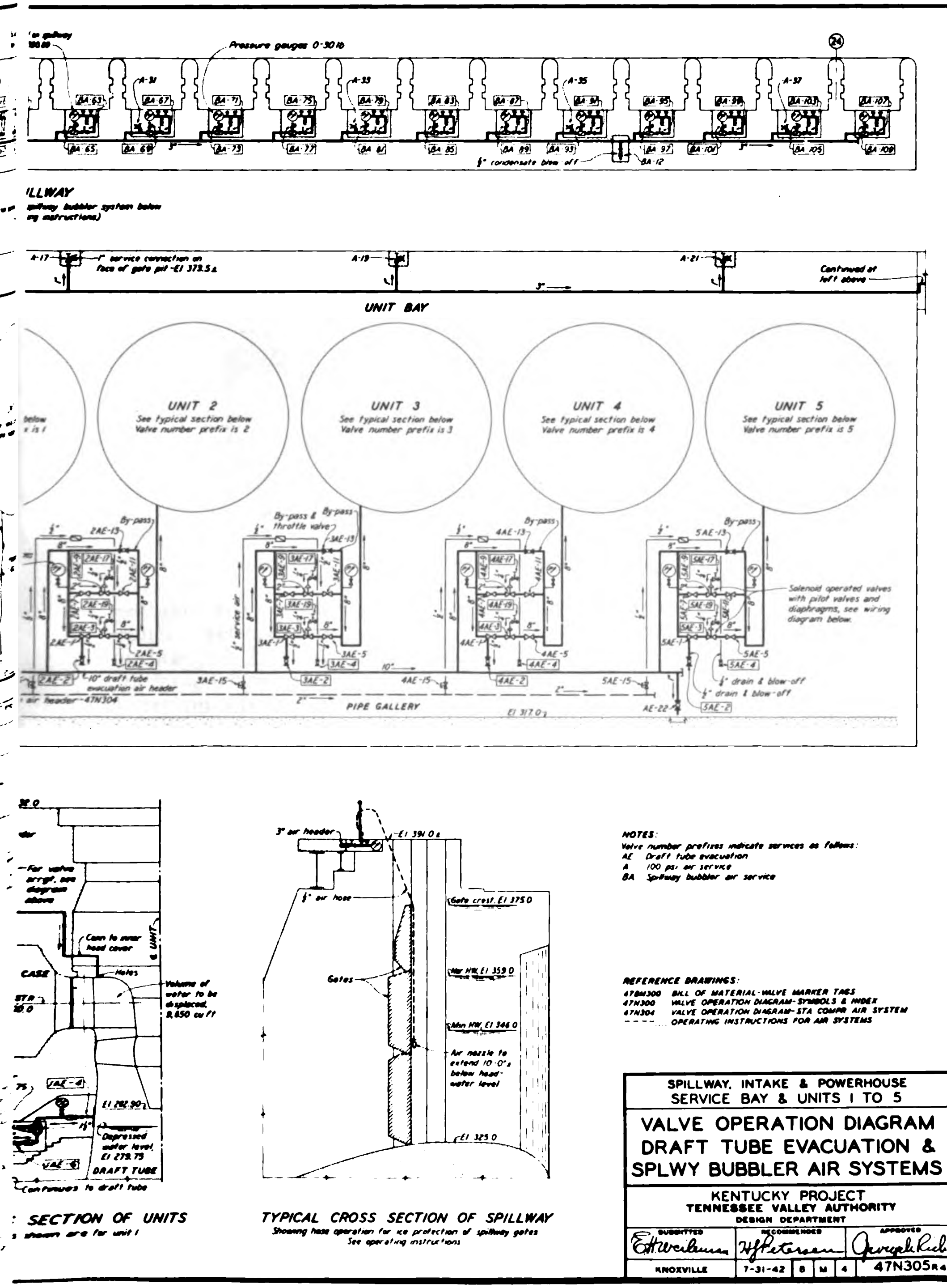

Pressure gauges 0-30 lb
A-31
A-33
A-35
A-37
BA-63
BA-67
BA-71
BA-75
BA-79
BA-83
BA-87
BA-91
BA-95
BA-99
BA-103
BA-107
BA-65
BA-69
BA-73
BA-77
BA-81
BA-85
BA-89
BA-93
BA-97
BA-101
BA-105
BA-109
BA-12
condensate blow off
A-17
service connection on face of gate pit -El 373.5
A-19
A-21
Continued at left above
UNIT BAY
UNIT 2
See typical section below
Valve number prefix is 2
UNIT 3
See typical section below
Valve number prefix is 3
UNIT 4
See typical section below
Valve number prefix is 4
UNIT 5
See typical section below
Valve number prefix is 5
By-pass
By-pass & throttle valve
Solenoid operated valves with pilot valves and diaphragms, see wiring diagram below.
10" draft tube evacuation air header
PIPE GALLERY
drain & blow-off
NOTES:
Valve number prefixes indicate services as follows:
AE Draft tube evacuation
A 100 psi air service
BA Spillway bubbler air service
REFERENCE DRAWINGS:
47BM300 BILL OF MATERIAL-VALVE MARKER TAGS
47N300 VALVE OPERATION DIAGRAM-SYMBOLS & INDEX
47N304 VALVE OPERATION DIAGRAM-STA COMPR AIR SYSTEM
---- OPERATING INSTRUCTIONS FOR AIR SYSTEMS
3" air header
Gate crest El 375.0
Gates
Nor HW El 359.0
Min HW El 346.0
Air nozzle to extend 10'-0" below head-water level
El 325.0
Volume of water to be displaced, 9,650 cu ft
Depressed water level El 279.75
DRAFT TUBE
Continues to draft tube
SECTION OF UNITS
TYPICAL CROSS SECTION OF SPILLWAY
Showing hose operation for ice protection of spillway gates
See operating instructions
SPILLWAY, INTAKE & POWERHOUSE
SERVICE BAY & UNITS 1 TO 5
VALVE OPERATION DIAGRAM
DRAFT TUBE EVACUATION &
SPLWY BUBBLER AIR SYSTEMS
KENTUCKY PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
7-31-42
47N305R4

PLATE 16

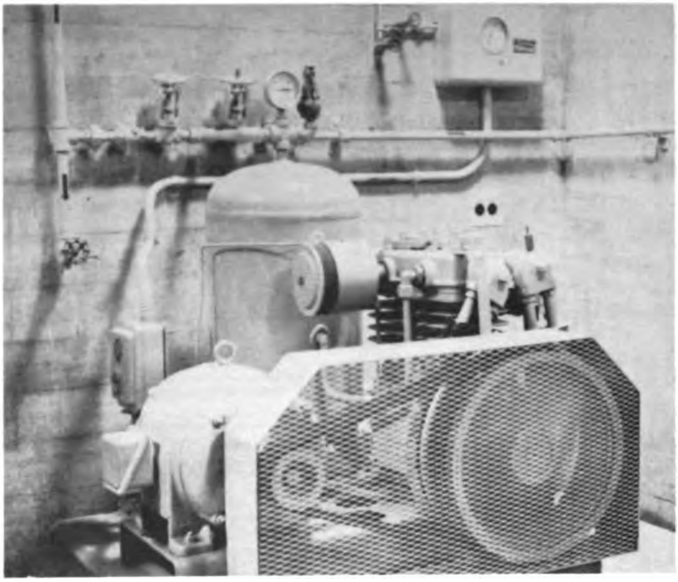


FIGURE 211.—*Typical governor air compressor—Chatuge.*

The governor and station air systems are combined on five plants—Wilbur, South Holston, Ocoee No. 3, Chatuge, and Nottely. Since these stations are small and unattended, the demand for station service is very light. For this reason the customary stationary air compressor for station air service was eliminated and the governor air compressor furnished to supply both systems. Plate 17 illustrates a typical system of this type at Ocoee No. 3. Air is supplied by an 8-cubic-foot-per-minute, 300-pound-per-square-inch compressor supplemented by a 105-cubic-foot-per-minute, 100-pound-per-square-inch portable compressor.

In normal operation the compressor is connected to supply the station air receiver. A gage-type pressure governor automatically maintains pressure in the receiver at 100 pounds per square inch. When it is desired to replenish air in the governor tank, the station air receiver is valved off and a selector switch is positioned to allow the pressure switch furnished with the compressor to maintain pressure in the governor air system at 300 pounds per square inch. Air is then bled into the governor pressure tank as required.

VIBRATION AIR SYSTEM

At the Guntersville project a compressed air system was installed to eliminate vibration which occurred in the structures of the first three generating units. Investigations indicated that these objectionable vibrations originated in the draft tubes, which have splitters of rather unusual profile. The severity of vibration increased directly with increases of load on the generating units. Exhaustive

studies and experiments were made in an effort to dampen these vibrations by altering the elastic properties of the structure. None of these experiments proved successful enough to justify further efforts along these lines. Modification of the splitters did not appear practicable because of the undesirable changes which might occur in the hydraulic characteristics of the draft tubes and the considerable outage of the generating units which would be required for such alterations.

Extensive tests were conducted in an attempt to eliminate vibration by introducing varying amounts of compressed air into the draft tubes under several combinations of pressure and at various generator loadings. Introduction of air below the runner created sufficient air bubbles in the water to provide a compressible mixture and considerable relief from vibration in the structure. The best results during the various tests were obtained when admitting compressed air simultaneously to all three draft tubes. From these tests it was concluded that approximately 105 cubic feet per minute of compressed air at approximately 80 pounds per square inch was required for each draft tube to reduce vibration to minimum when the unit was operating at maximum overload.

A permanent compressed air system was then installed for vibration elimination. Some of the details of this system are shown in plates 18 and 19. This system is supplied by a stationary air compressor rated at 472 cubic feet per minute at 100 pounds per square inch. This compressor also supplies air for the evacuation system, since both systems will not be in operation at the same time at any one unit. Both systems are provided with 2,700 cubic feet of air storage.

A 3-inch air main is routed from the receivers through the operating pipe gallery alongside the units. Branch lines of 1¼-inch size are installed from the pipe main down to the access of each draft tube. Each original draft tube installation included an embedded ¾-inch pipe ring header around the draft tube liner with six 1-inch taps into the throat of the liner. This arrangement originally conveyed draft tube vacuum and pressure readings through a diaphragm box to a gage mounted on the governor cabinet. To facilitate equal distribution of compressed air being supplied to the draft tube for vibration elimination, this embedded ring header was utilized by connection to the 1¼-inch vibration air branch line. A shutoff valve, regulating valve, and a duplex air pressure gauge are installed in each branch supply in the pipe gallery where they are convenient to the operator. These accessories enable the operator to throttle the air supply to the desired pressure for optimum results for each individual generating unit.

As described in chapter 2, page 191, compressed air was initially used at the Fontana project to assist in alleviating vibration in the turbine until permanent fins were installed in the draft tubes to break up the centrifugal action of the water leaving the runner.

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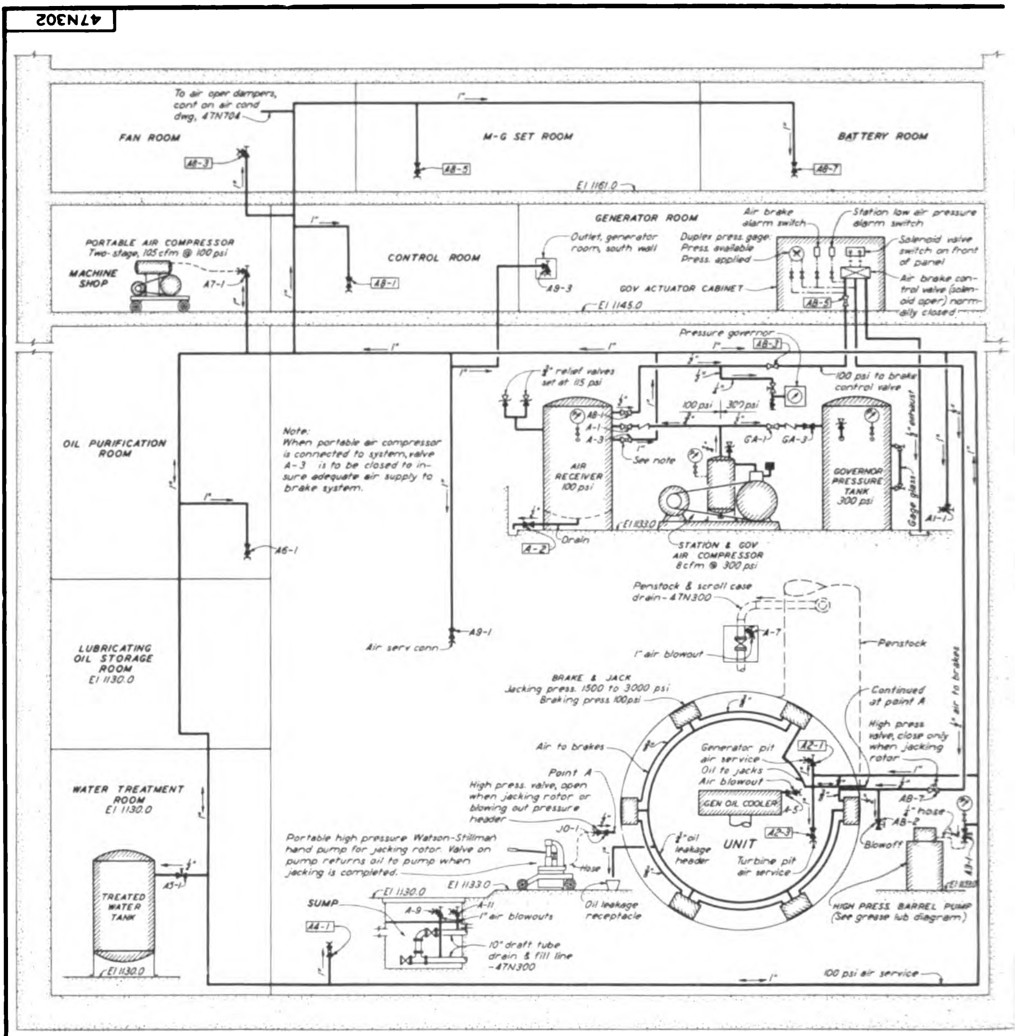
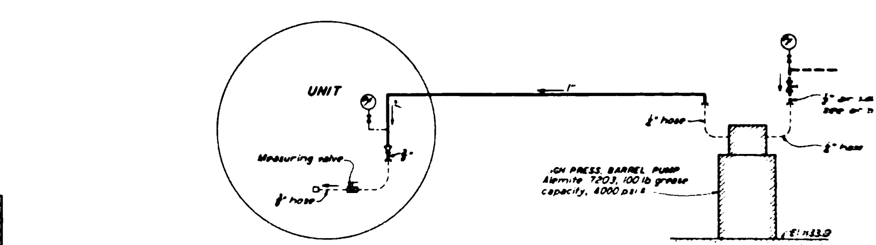


100 PSI & 300 PSI COMPRESSED AIR SYSTEMS



GREASE LUBRICATION SYSTEM

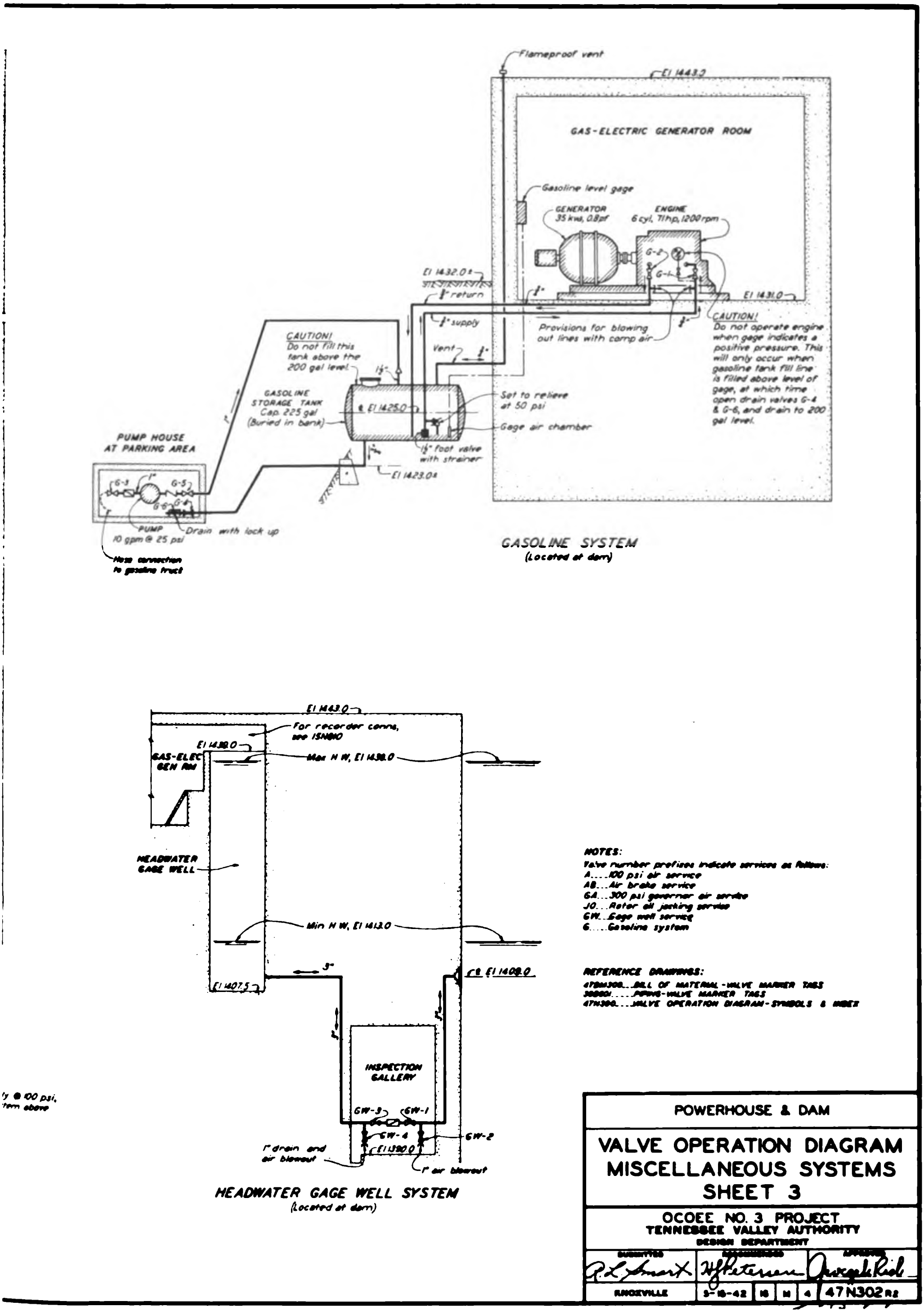
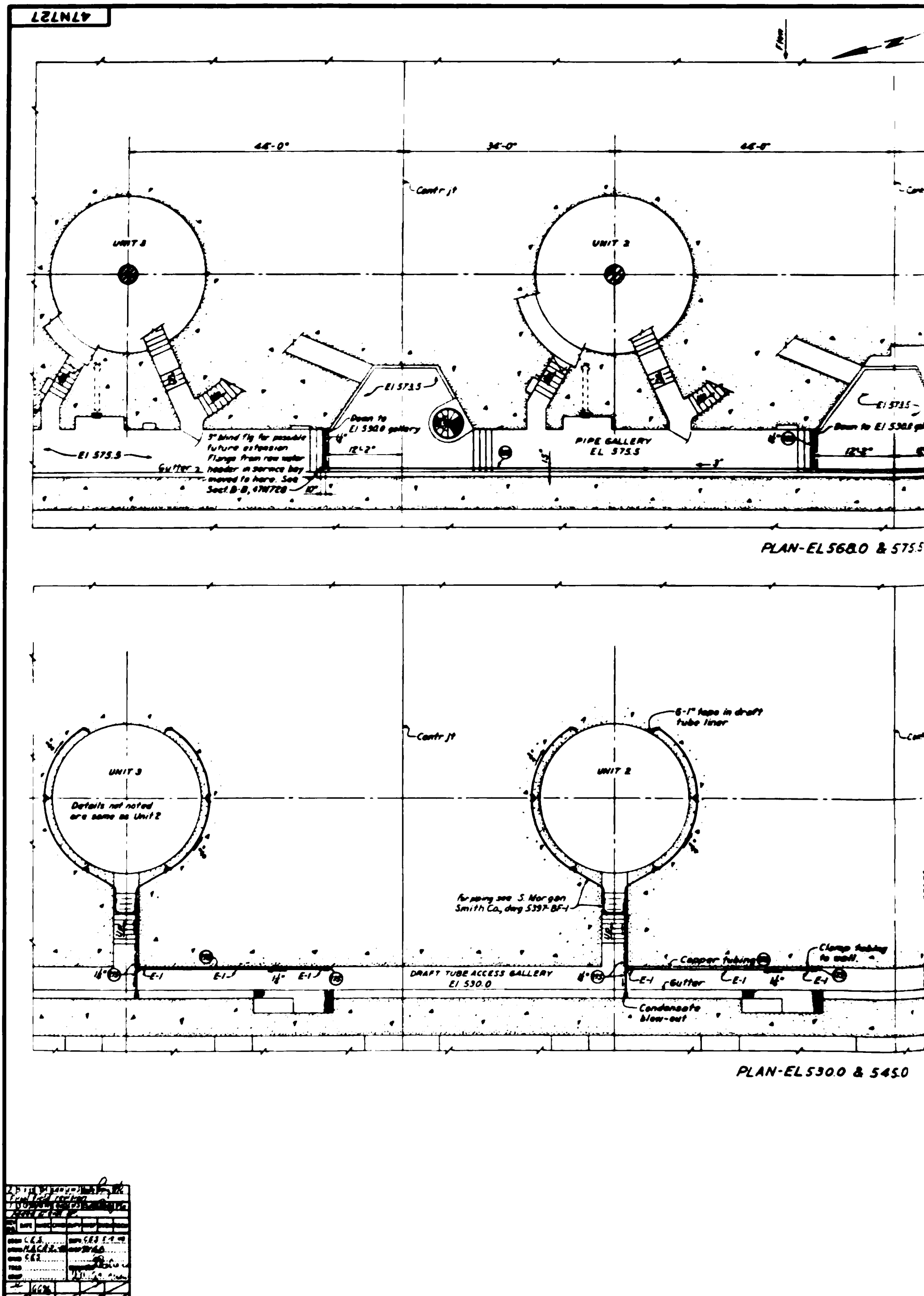
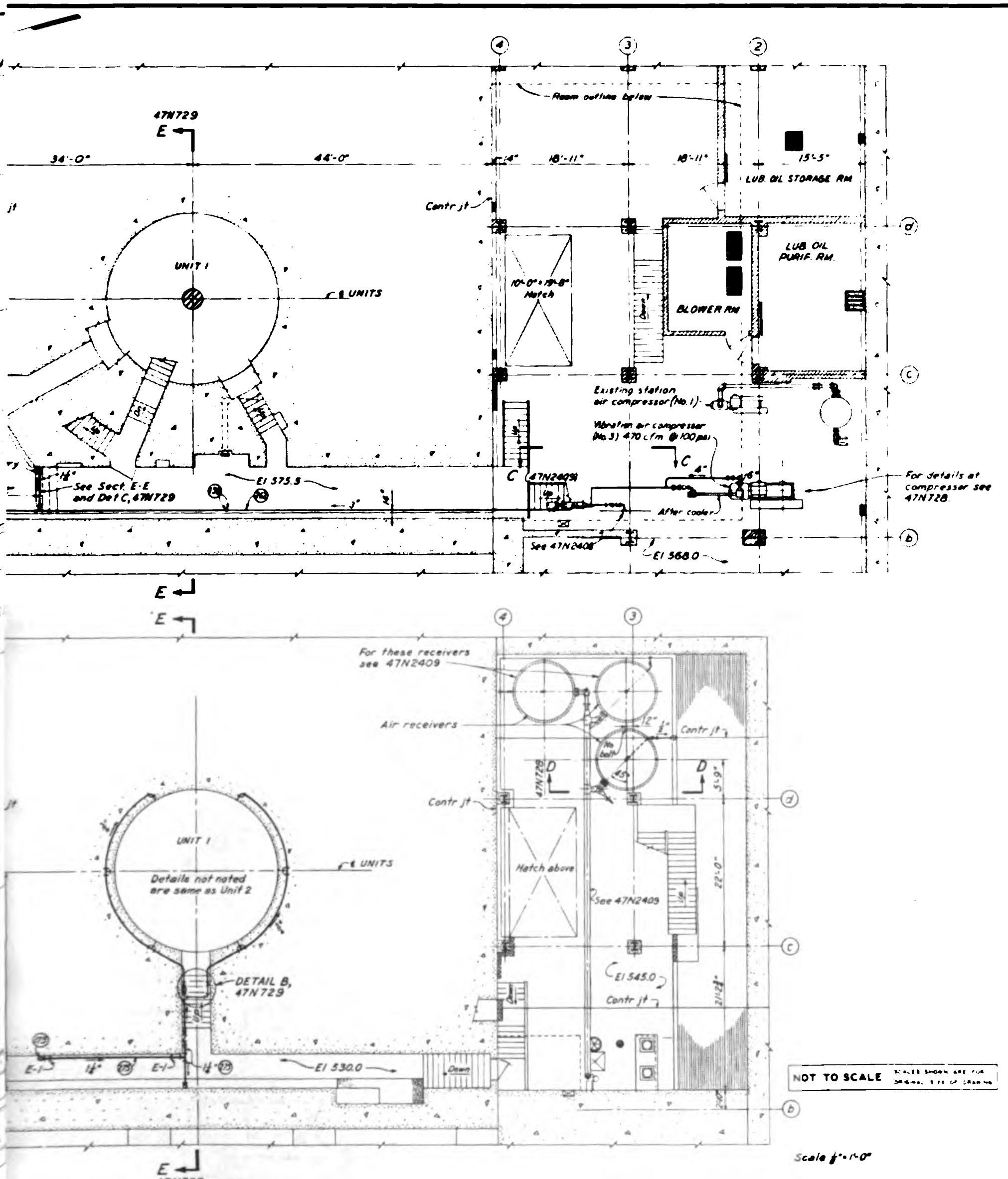

Flameproof vent
El 1443.0
GAS-ELECTRIC GENERATOR ROOM
Gasoline level gage
GENERATOR
35 kva, 0.8pf
ENGINE
6 cyl, 71hp, 1200 rpm
El 1432.0±
½" return
½" supply
El 1431.0
CAUTION!
Do not operate engine when gage indicates a positive pressure. This will only occur when gasoline tank fill line is filled above level of gage, at which time open drain valves G-4 & G-6, and drain to 200 gal level.
Provisions for blowing out lines with comp air
CAUTION!
Do not fill this tank above the 200 gal level.
Vent
GASOLINE STORAGE TANK
Cap. 225 gal
(Buried in bank)
El 1425.0
Set to relieve at 50 psi
Gage air chamber
1½" foot valve with strainer
El 1423.0±
PUMP HOUSE AT PARKING AREA
PUMP
10 gpm @ 25 psi
Drain with lock up
Hose connection to gasoline truck
GASOLINE SYSTEM
(Located at dam)
El 1443.0
For recorder conns, see 15N810
El 1439.0
GAS-ELEC GEN RM
Max H W, El 1438.0
HEADWATER GAGE WELL
Min H W, El 1413.0
El 1407.5
El 1409.0
INSPECTION GALLERY
GW-3
GW-1
GW-4
GW-2
El 1390.0
1" drain and air blowout
1" air blowout
HEADWATER GAGE WELL SYSTEM
(Located at dam)
NOTES:
Valve number prefixes indicate services as follows:
A....100 psi air service
AB...Air brake service
GA...300 psi governor air service
JO...Rotor oil jacking service
GW..Gage well service
G....Gasoline system
REFERENCE DRAWINGS:
47BM300...BILL OF MATERIAL-VALVE MARKER TAGS
15B801...PIPING-VALVE MARKER TAGS
47N300...VALVE OPERATION DIAGRAM-SYMBOLS & INDEX
POWERHOUSE & DAM
VALVE OPERATION DIAGRAM
MISCELLANEOUS SYSTEMS
SHEET 3
OCOEE NO. 3 PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
3-16-42
47N302 R2

PLATE 17


PLAN-EL 568.0 & 575.5
PLAN-EL 530.0 & 545.0
UNIT 3
UNIT 2
PIPE GALLERY EL 575.5
DRAFT TUBE ACCESS GALLERY El 530.0
Details not noted are same as Unit 2



NOTES:

1. All lines shall be standard weight black steel or wrought iron pipe unless otherwise noted.
2. B-2, etc. indicates pipe supports as detailed on 47N729.
3. Field shall insulate all cooling water supply piping to prevent sweating.
4. For manufacturer's details of
   (a) 470 cfm air compressor, refer to R L Harris, Inc file TVA Contract No TV-278A
   (b) Air receiver, refer to Truitt Mfg Co file, TVA Contract No TV 468A.

REFERENCE DRAWING

47BM727. PIPING BILL OF MATERIAL

COMPANION DRAWINGS. 47N728 & 47N729

POWERHOUSE
SERVICE BAY & UNITS 1, 2, & 3

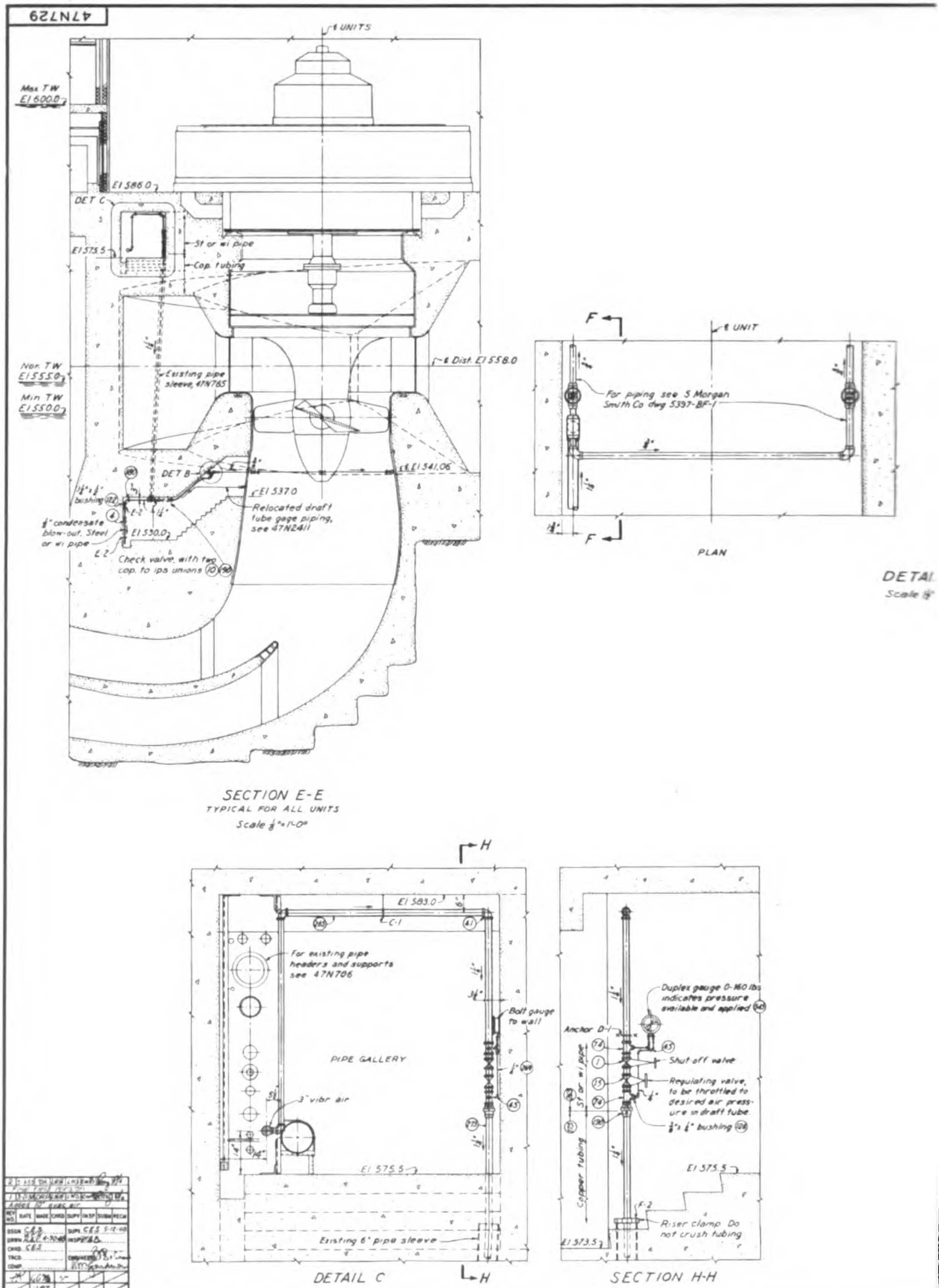
MECHANICAL
VIBRATION COMPRESSED
AIR SYSTEM – SHEET I

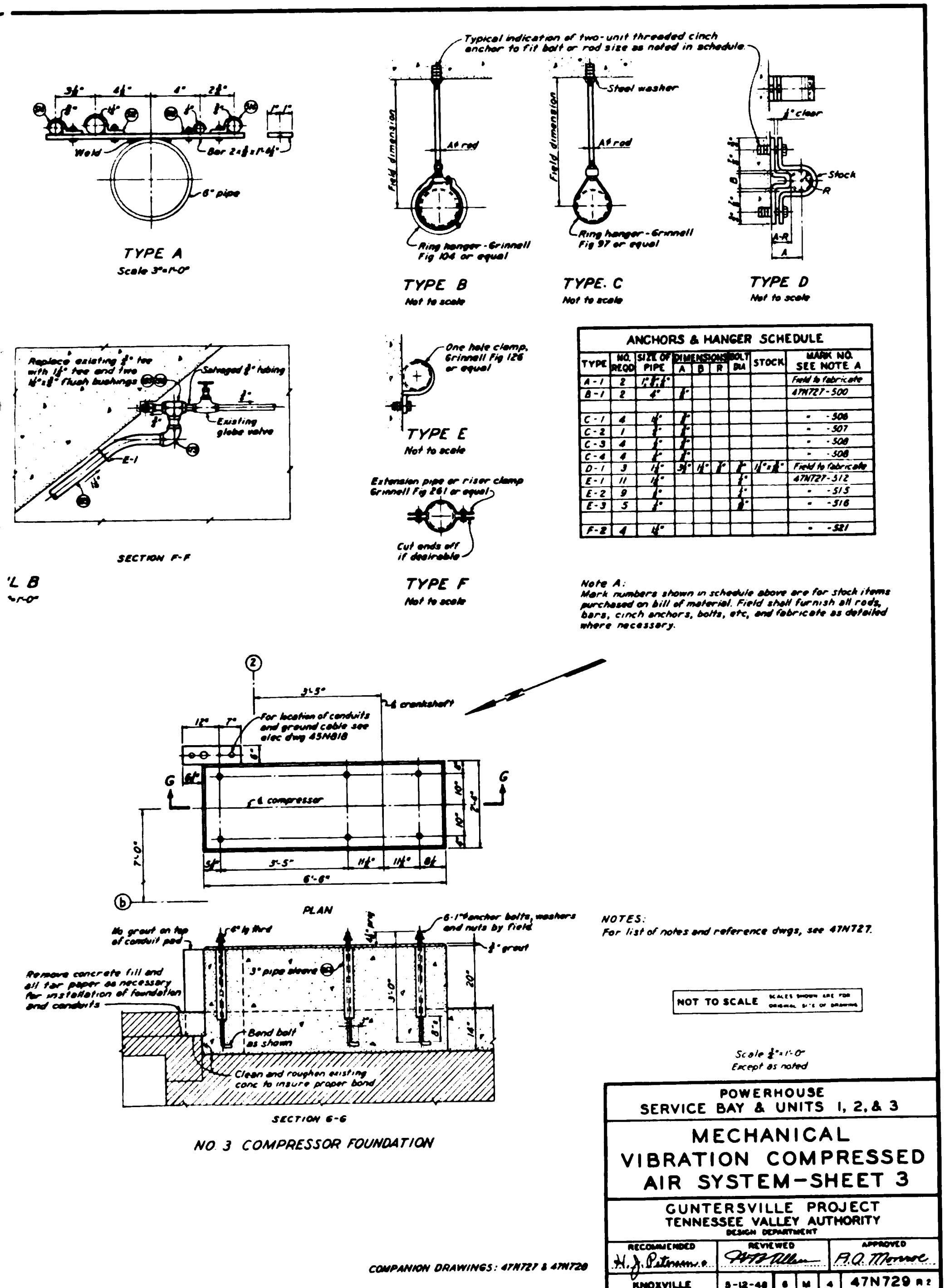
GUNTERSVILLE PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

RECOMMENDED	REVIEWED	APPROVED
H. J. Petersen	W. B. Allen	R. A. Monroe

KNOXVILLE	5-12-48	6	M	4	47N727 R2

PLATE 18


47N729
℄ UNITS
Max TW
El 600.0
El 586.0
DET C
El 575.5
St or wi pipe
Cop. tubing
Existing pipe sleeve, 47N765
Nor. TW
El 555.0
Min TW
El 550.0
℄ Dist. El 558.0
DET B
℄ El 541.06
El 537.0
Relocated draft tube gage piping, see 47N2411
¼" condensate blow-out. Steel or wi pipe
El 530.0
Check valve, with two cop. to ips unions
SECTION E-E
TYPICAL FOR ALL UNITS
Scale ⅛" = 1'-0"
F
℄ UNIT
For piping see S Morgan Smith Co dwg 5397-BF-1
PLAN
DETAIL
El 583.0
C-1
For existing pipe headers and supports see 47N706
Bolt gauge to wall
PIPE GALLERY
3" vibr air
El 575.5
Existing 6" pipe sleeve
DETAIL C
H
Duplex gauge 0-160 lbs indicates pressure available and applied
Anchor D-1
Shut off valve
Regulating valve, to be throttled to desired air pressure in draft tube
St or wi pipe
Copper tubing
El 575.5
F-2
Riser clamp. Do not crush tubing
El 573.5
SECTION H-H



ANCHORS & HANGER SCHEDULE

TYPE	NO. REQD	SIZE OF PIPE	DIMENSIONS A	DIMENSIONS B	DIMENSIONS R	BOLT DIA	STOCK	MARK NO. SEE NOTE A
A-1	2	[illegible]						Field to fabricate
B-1	2	4"	[illegible]					47N727-500
C-1	4	[illegible]	[illegible]					" -506
C-2	1	[illegible]	[illegible]					" -507
C-3	4	[illegible]	[illegible]					" -508
C-4	4	[illegible]	[illegible]					" -508
D-1	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Field to fabricate
E-1	11	[illegible]				[illegible]		47N727-512
E-2	9	[illegible]				[illegible]		" -515
E-3	5	[illegible]				[illegible]		" -516
F-2	4	[illegible]						" -521

Note A:
Mark numbers shown in schedule above are for stock items purchased on bill of material. Field shall furnish all rods, bars, cinch anchors, bolts, etc., and fabricate as detailed where necessary.

NOTES:
For list of notes and reference dwgs, see 47N727.

COMPRESSOR CONTROL

Stationary air compressors used by TVA are provided with dual control—automatic start and stop control in combination with constant-speed control. With automatic start and stop control the compressor can be automatically stopped when the desired pressure is obtained, then automatically restarted when a minimum lower pressure is reached. With constant-speed control the compressor runs continuously, but unloaded with the suction valves held open when the desired discharge pressure is reached, thus preventing further compression of air. Start and stop control is normally used for stationary air compressors, since the demand for air in TVA hydro plants is intermittent, with long periods of no demand. It is not used, however, if there are more than eight starts per hour, since too frequent starting tends to overload the motor.

Manufacturers differ on methods of accomplishing dual control. One typical dual-control system, shown in figure 212, includes a pressure switch, three-way solenoid valve, a time delay device, and a selector switch marked "Auto-Off-Hand." A control line is run from near the top of the air receiver to the pressure switch, and on to the three-way solenoid valve which controls flow to the diaphragm chambers of the compressor unloaders. A needle valve is located in the line to the pressure switch for lessening pressure fluctuations. A strainer, or moisture trap, is placed in the control line preceding the three-way solenoid valve. The purpose of this trap is to remove any moisture and grit that might have come from the air receiver before it reaches the solenoid valve. For automatic start and stop control the selector switch is set at "Auto" and the compressor and motor will automatically start and stop in accordance with the demand of the air receiver. When the pressure drops to the predetermined starting pressure, the pressure switch starts the motor and energizes the three-way solenoid valve. This action causes air in the lines to the diaphragm chambers of the compressor unloaders to be vented to atmosphere, closing the compressor inlet valves and allowing air to be compressed and delivered to the line. A time delay device retards the air from bleeding out of the diaphragm chambers, thereby keeping the inlet valves open until the motor reaches full speed. The machine runs until a predetermined stopping pressure is reached, at which time the pressure switch automatically stops the motor and unloads the compressor. The pressure switch deenergizes the three-way solenoid valve, allowing receiver pressure to pass through to the diaphragm chambers of the compressor unloaders. The unloaders hold the inlet valves open, allowing air to sweep in and out of the cylinder without being compressed.

On two-stage compressors with an intercooler between stages, a release valve is provided to vent the intercooler pressure to atmosphere when the cylinders are unloaded. For constant-speed control the selector switch is set at "Hand." The motor runs continuously and is not controlled by the pressure switch. When the receiver pressure rises to the high limit of cutout setting of the pressure switch, the solenoid valve is deenergized and the compressor

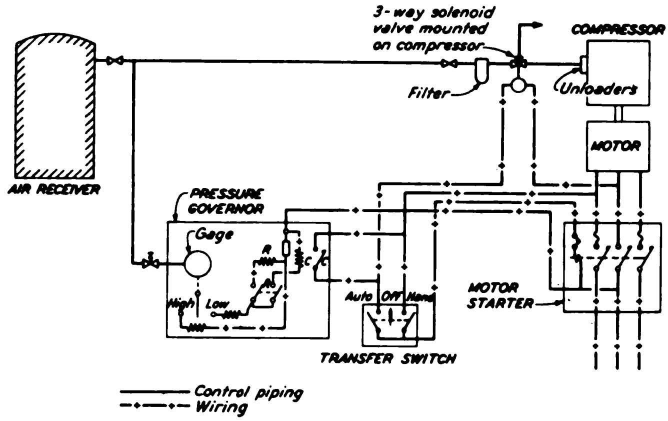


FIGURE 212.—*Air compressor dual control diagram.*

unloaded as previously described. When the pressure drops to the low limit setting of the pressure switch, the three-way solenoid valve is energized and the compressor loaded as described previously. When it is desired to stop the compressor, the selector switch is set at the "Stop" position.

Water-cooled compressors are furnished with a solenoid or air-operated valve which shuts off the cooling water supply to the cylinder jacket when the compressor is not running and opens when the compressor is started. A globe-type throttling valve is placed in the cooling water supply line to help control the discharge temperature.

Operation requirements for portable air compressors dictate that they have constant-speed control. They are normally equipped with a mechanical pilot valve type unloading device with provision for manual unloading for starting, until the motor is up to speed.

TVA specifies that the governor air compressor, furnished by the governor contractor, be equipped with an unloading device which will unload the compressor to atmosphere whenever the motor stops and maintain this condition until the motor is running at full speed. The compressors furnished are usually equipped for automatic start and stop control with centrifugal or vacuum unloaders.

COMPRESSOR SPECIFICATIONS

TVA specifies that the larger compressors, with capacities between 100 and 600 cubic feet of free air per minute at a discharge pressure of 100 pounds per square inch, shall be stationary, electric-motor-driven with V-belt drive, water-cooled, and shall be either of horizontal-, vertical-, Y-, or L-type construction. Normally a single-stage horizontal- or vertical-type machine is furnished. These machines are capable of giving continuous service over a period of years with very little maintenance due to their very durable construction.

Smaller capacity air compressors, rated at 60 to 115 cubic feet of free air per minute at a discharge pressure of 100 pounds per square inch, are specified as stationary, electric-motor-driven, direct-connected, 2-stage, air-cooled units. Although not considered to be as durable as the general type mentioned above, they are considered adequate for the types of service for which they will be used and have the advantage of lower first cost and slightly lower operating cost for their capacity range.

Governor air compressors are furnished by the governor contractor and are stationary, electric-motor-driven, 2-stage, air-cooled units furnished with a receiver mounted with the motor and compressor. The governor air compressor for the Chatuge project is shown in figure 211.

Portable air compressors are specified to be fully air-cooled, or air-cooled by a fluid medium in a radiator, 2-stage, driven by a direct-connected electric motor, provided with a suitable air receiver, and mounted on a truck equipped with a towing tongue and lifting hooks. A typical portable air compressor is shown in figure 213.

Complete procurement specifications for a draft tube evacuation air compressor and a portable air compressor are included in appendix B.

PIPING

Black steel ASTM A 120 pipe and black steel welding fittings or black cast-iron flanged fittings are used for all compressed air piping of 3-inch size or larger. Normally, for sizes under 3 inches, black wrought-iron ASTM A 72 pipe is used for embedded compressed air piping and black steel ASTM A 120 piping used for exposed compressed air piping, but the two may be substituted for each other. Screwed black malleable-iron fittings are used for all low-pressure

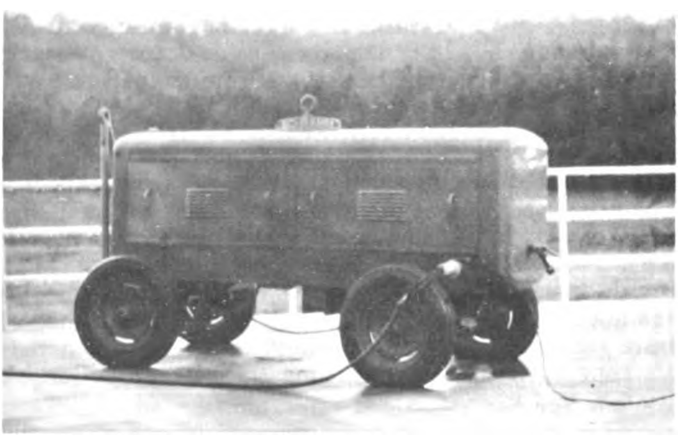


FIGURE 213.—*Typical motor-driven portable air compressor—Chatuge.*

(100 pounds per square inch and lower) compressed air piping for sizes below 3 inches; however, combination compressed air and jacking oil piping encountering pressures up to 2,000 pounds per square inch require black forged steel fittings.

Large valves in compressed air systems are IBBM gate type, and smaller valves are bronze gate or globe depending upon their function in the system. Check valves are either IBBM or bronze swing check type, depending upon size.

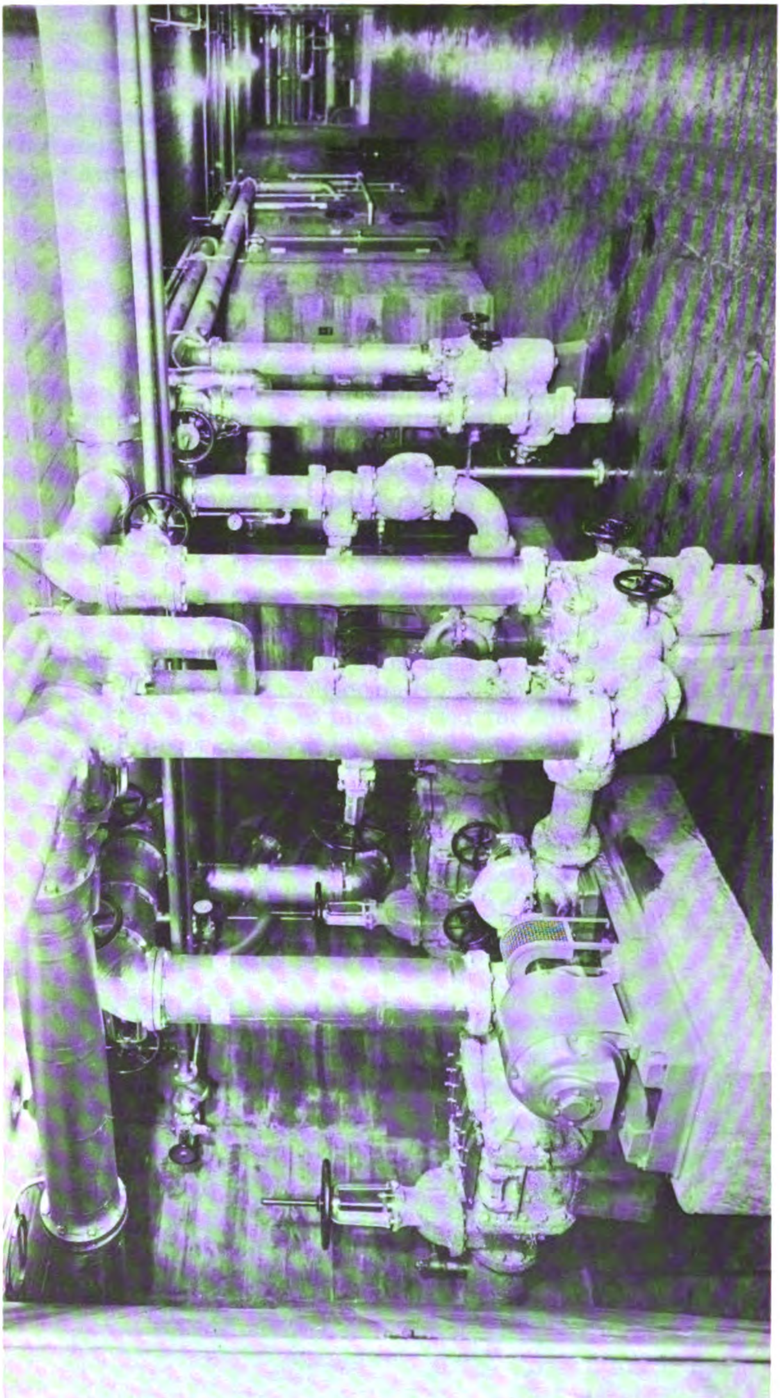


FIGURE 214.—*Generator cooling water pumps—Chickamauga.*

Chapter 8

RAW WATER SYSTEMS

Raw water is used at hydro plants for station service, unit cooling and lubrication, fire protection, and miscellaneous uses. All these services are treated in this chapter except fire protection, which is discussed separately in chapter 13.

Source of supply

For convenience the raw water supply for unit cooling and turbine bearing lubrication is normally taken from the penstock or scroll case. An intake for the normally integrated fire-protection and station service systems other than at the penstock or scroll case is necessary in order to make these services available at times when the penstock is unwatered. This intake is usually located on the upstream face of the dam. At plants where the powerhouse is located some distance downstream from the intake structure, such as Chatuge and Nottely, fire and service water is taken from the penstock or scroll case in the powerhouse because of the impracticality of bringing it through a separate pipeline from the dam or intake structure.

System data

In all plants an intake for unit cooling and lubrication is provided for each unit with the supply lines between units manifolded or cross connected for flexibility. Bar grates at the entrance to the piping system prevent large sticks or stones from entering. A hose connection for air blowout is provided for clearing the grate in case it becomes clogged. Twin- or multiple-type strainers are used on all supply lines. Table 8 presents raw water cooling and service system data for each of the TVA-built hydro plants and unit additions.

Water pressures

Unit cooling and lubricating water pressure is usually limited to a maximum pressure of 40 pounds per square inch to prevent damage to the generator air coolers and other equipment. For most efficient service a pressure of approximately 80 pounds per square inch is required for fire protection although lower pressures are sometimes utilized. Station service and other miscellaneous raw water uses, which are normally integrated with the fire-protection system, require pressure reduction in a few instances.

TABLE 8.—*Raw water cooling and service system data*

Project	Type flow, unit cooling system	System control	Maximum GPM flow requirement—one unit: Gen air coolers	Gen bearing oil coolers	Turbine bearing	Design capacity, unit cooling water pump: Gpm	Tdh	Motor (hp)	Unit cooling pressure regulating valves (total per plant): Number	Size	Capacity (gpm each)[e]	Maximum inlet pressure (psi)	Outlet pressure (psi)	Gen Air cooling proportioning valve (size)	Plant service system: Source[f]	Type flow
										Inches				*Inches*		
Norris	Gravity	Remote	840	60	[b, d] 300				1	8	5,350	76	30	4	T.W.	Gravity.
Wheeler	Pumped	Manual	1,080	100	200	1,300	50	20							T.W.	Do.
Pickwick Units 1–4	do	do	1,000	75	140	1,300	30	15							T.W.	Do.
Pickwick Units 5 and 6	do	do	1,000	60	140	1,300	40	20								
Guntersville Units 1–3	do	do [a]	1,000	200	115	1,300	50	25							R.W.	Pumped.
Guntersville Unit 4	do	do [a]	1,000	100	115	1,300	50	25								
Chickamauga	do	do [a]	1,000	100	100	1,100	34–35	15							R.W.	Do.
Hiwassee Unit 1	Gravity	Remote	[g] 720	50	[b, d] 230				1	8	2,500	110	36	4	T.W.	Gravity.
Hiwassee Unit 2	do	do	[g] 1,175	150	[b, d] 160									6		
Watts Bar	Pumped	Manual	900	35	175	1,200	35	15							T.W.	Do.
Wilson Units 9–18	Gravity	do [a]	875	20	[b, d] 200										T.W.	Do.
Cherokee	do	Remote	600	100	[b, d] 70									4	T.W.	Do.
Douglas	do	do[a]	600	30–100	[b, d] 70									4	T.W.	Do.
Ocoee No. 3	do	do[a]	640	15	[b, d] 200				1	6	800	195	40	6	R.W.	Do.
Apalachia	do	Manual [a]	925	35	200				2	8	1,200	270	40		R.W.	Do.
Fort Loudoun	do	do	1,140	50	175										T.W.	Do.
Kentucky	Pumped	do	900	100	200	1,200	35	15							T.W.	Do.
Fontana	Gravity	Remote	900	63	[b, d] 185				1	8	3,600	182	40	4	R.W.	Do.
Watauga	do	do	595	25	[b, d] 230				2	4	1,000	145	40	6	R.W.	Do.
Wilbur Unit 4	do	do	200	9	50									4	R.W.	Do.
South Holston	do	do	845	33	[b, d] 65				2	4	1,130	108	40	5	T.W.	Do.
Hales Bar Units 15 and 16.	Pumped	do	1,000	100	[d] 115	1,300	50	25						8	R.W.	Pumped.
Boone	Gravity	do	665	20	[b, d] 100									4	R.W.	Do.
Fort Patrick Henry	do	do	420	36	[b, d] 75									3	R.W.	Do.
Chatuge	do	do	290	10	[c, d] 150									3	R.W.	Gravity.
Nottely	do	do	445	18	[c, d] 200									3	R.W.	Do.

[a] Estimates have been prepared as of September 1, 1955, covering addition of remote controls.
[b] Oil-lubricated bearing—All others water-lubricated except as noted.
[c] Grease-lubricating bearing.
[d] Includes supply to runner seals.
[e] Maximum anticipated flow.
[f] R.W.=raw water; T.W.=treated water.
[g] Assumed maximum temperature of 17.5 C.

To obtain the required pressure, pumping is required for almost all raw water services in the main river plants with the exception of Wilson and Fort Loudoun which have adequate headwater pressure. Plate 20 presents a flow diagram of a typical pumped system and figure 214 shows the arrangement of the unit cooling water pumps at Chickamauga.

At some medium head plants pumping is required for the fire and service system, but unit cooling and lubrication is effected by gravity flow. Plate 21 shows a typical flow diagram of the Fort Patrick Henry project where unit cooling water is supplied by gravity flow (no pressure reduction required). If pumping is required for unit cooling one pump is provided per unit, with an emergency pump to supply water to any or all units in case regular pumps fail or are inadequate.

In the high head plants pressure must be reduced by pressure regulating valves for most raw water services. A relief valve on the low-pressure side of each pressure regulating valve protects against piping or equipment damage which might result from faulty operation of the valve. Plate 22 is a flow diagram of the Fontana raw water system, which is a typical high head gravity flow system. At Fontana the raw water supply has a maximum inlet pressure of 182 pounds per square inch which is reduced to a constant pressure of 40 pounds per square inch for unit cooling and lubrication, and to 80 pounds per square inch for fire protection and station service. This is effected by air-operated pressure reducing valves. At this plant an air chamber charged with 100-pound-per-square-inch compressed air is installed on the raw water intake manifold, to keep down shock and water hammer due to sudden valve closure.

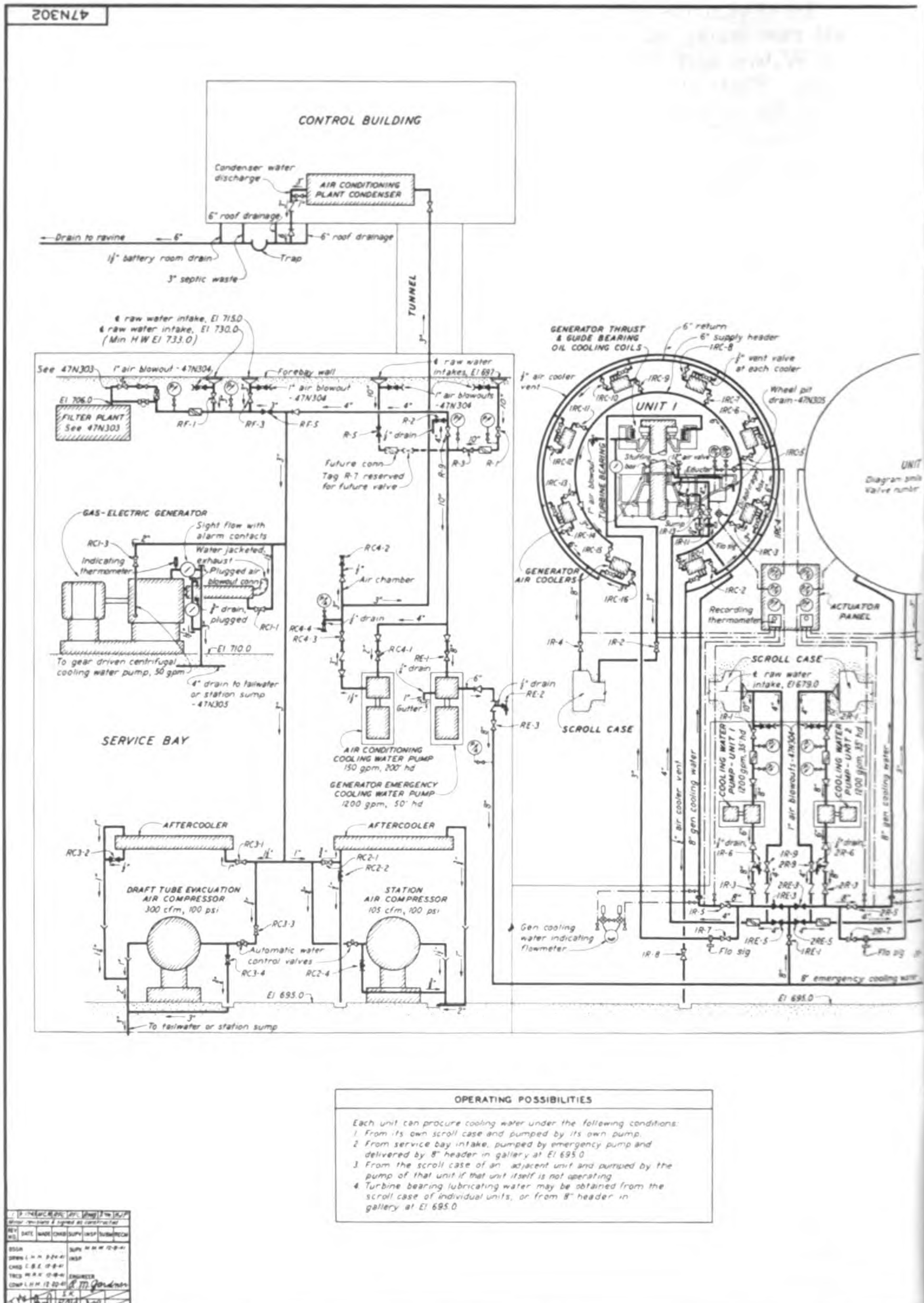
Plate 23 and figure 215, page 446, show a typical arrangement of pressure regulating and relief valves at the Watauga project.

At Chatuge and Nottely all raw water services are effected by gravity flow. This results in rather low pressure at several fire hose outlets at both plants during periods of extremely low headwater. Since this condition occurs rarely, both stations are remotely controlled, and other firefighting equipment is considered adequate for an emergency, the added expense of a pump and necessary piping was deemed unnecessary.

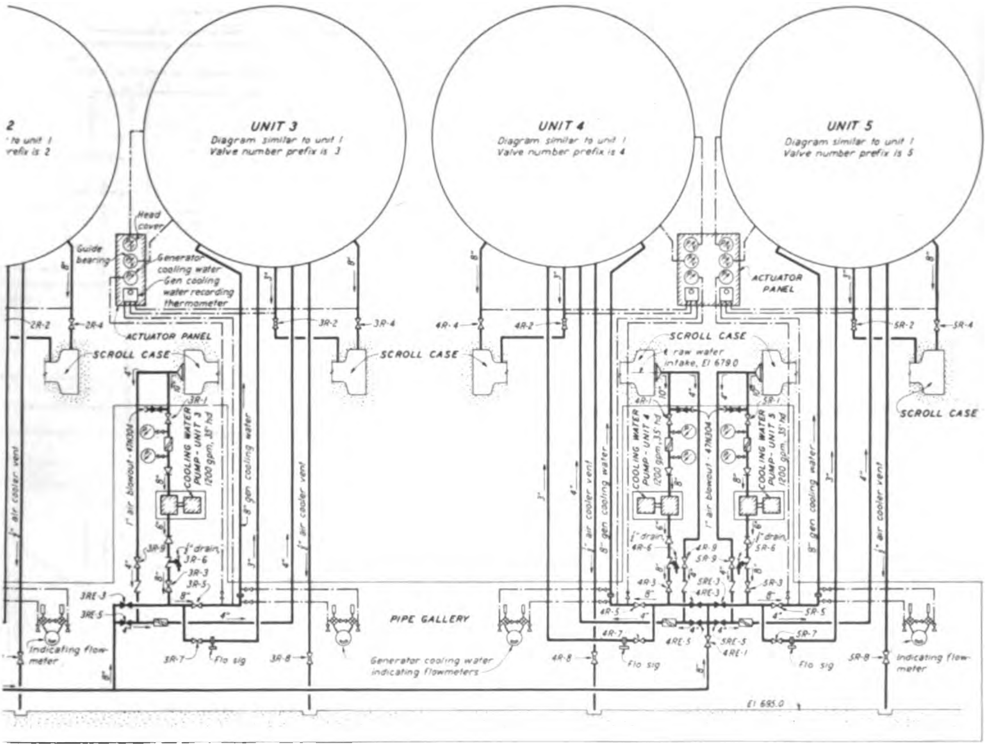
Special operating instructions such as that shown in appendix E are sometimes prepared and issued to operating personnel covering particular raw water systems.

STATION SERVICE

Numerous 1-inch service outlets consisting of a globe valve and universal hose coupling are placed throughout the powerhouse for deck and floor flushing. Naturally this type of system does not have rigid pressure requisites. Since it is normally integrated with the fire-protection system it may have pressures as high as 80 pounds per square inch. In a few plants where it is more convenient to do so, this service is taken from the treated water system.


47N302
CONTROL BUILDING
Condenser water discharge
AIR CONDITIONING PLANT CONDENSER
6" roof drainage
Drain to ravine
1½" battery room drain
Trap
3" septic waste
TUNNEL
℄ raw water intake, El 715.0
℄ raw water intake, El 730.0
(Min H W El 733.0)
See 47N303
1" air blowout - 47N304
Forebay wall
℄ raw water intakes, El 697
El 706.0
FILTER PLANT
See 47N303
RF-1
RF-3
RF-5
R-5
R-2
R-3
R-1
R-9
Future conn.
Tag R-7 reserved for future valve
GAS-ELECTRIC GENERATOR
Sight flow with alarm contacts
Water jacketed exhaust
Plugged air blowout conn.
Indicating thermometer
RC1-3
RC1-1
½" drain, plugged
El 710.0
To gear driven centrifugal cooling water pump, 50 gpm
4" drain to tailwater or station sump - 47N303
RC4-2
Air chamber
RC4-4
RC4-3
RC4-1
RE-1
RE-2
RE-3
Gutter
SERVICE BAY
AIR CONDITIONING COOLING WATER PUMP
150 gpm, 200' hd
GENERATOR EMERGENCY COOLING WATER PUMP
1200 gpm, 50' hd
AFTERCOOLER
AFTERCOOLER
RC3-2
RC3-1
RC2-1
RC2-2
DRAFT TUBE EVACUATION AIR COMPRESSOR
300 cfm, 100 psi
STATION AIR COMPRESSOR
105 cfm, 100 psi
RC3-3
Automatic water control valves
RC3-4
RC2-4
El 695.0
To tailwater or station sump
GENERATOR THRUST & GUIDE BEARING OIL COOLING COILS
6" return
6" supply header
½" vent valve at each cooler
1" air cooler vent
Wheel pit drain - 47N305
UNIT 1
TURBINE BEARING
GENERATOR AIR COOLERS
Recording thermometer
ACTUATOR PANEL
SCROLL CASE
℄ raw water intake, El 679.0
SCROLL CASE
COOLING WATER PUMP - UNIT 1
1200 gpm, 35' hd
COOLING WATER PUMP - UNIT 2
1200 gpm, 35' hd
1" air cooler vent
8" gen cooling water
1" air blowouts - 47N304
Gen cooling water indicating flowmeter
Flo sig
8" emergency cooling water
El 695.0
UNIT
Diagram sim
Valve numbe
OPERATING POSSIBILITIES
Each unit can procure cooling water under the following conditions:
1. From its own scroll case and pumped by its own pump.
2. From service bay intake, pumped by emergency pump and delivered by 8" header in gallery at El 695.0
3. From the scroll case of an adjacent unit and pumped by the pump of that unit if that unit itself is not operating
4. Turbine bearing lubricating water may be obtained from the scroll case of individual units, or from 8" header in gallery at El 695.0

MAXIMUM RAW WATER REQUIREMENTS OF EQUIPMENT		
Air coolers	900 gpm	Requirement per unit
Oil coolers	350 gpm	
Turbine bearing	175 gpm	
Gas electric generator engine	50 gpm	Service bay requirement
Gas electric generator exhaust	13 gpm	
Station air compressor engine	2.4 gpm	
Station air compressor aftercooler	1.2 gpm	
Draft tube evacuation air compressor engine	4.3 gpm	
Draft tube evacuation air compressor aftercooler	3.3 gpm	



Note
All flowmeters and flo sigs have low flow alarm contacts
The turbine bearing flo sig has an additional contact to shut down unit on lower flow.

NOTES:
Valve number prefixes indicate services as follows
R Raw water
RC Raw water, cooling
RE Raw water emergency
RF Raw water to filter plant

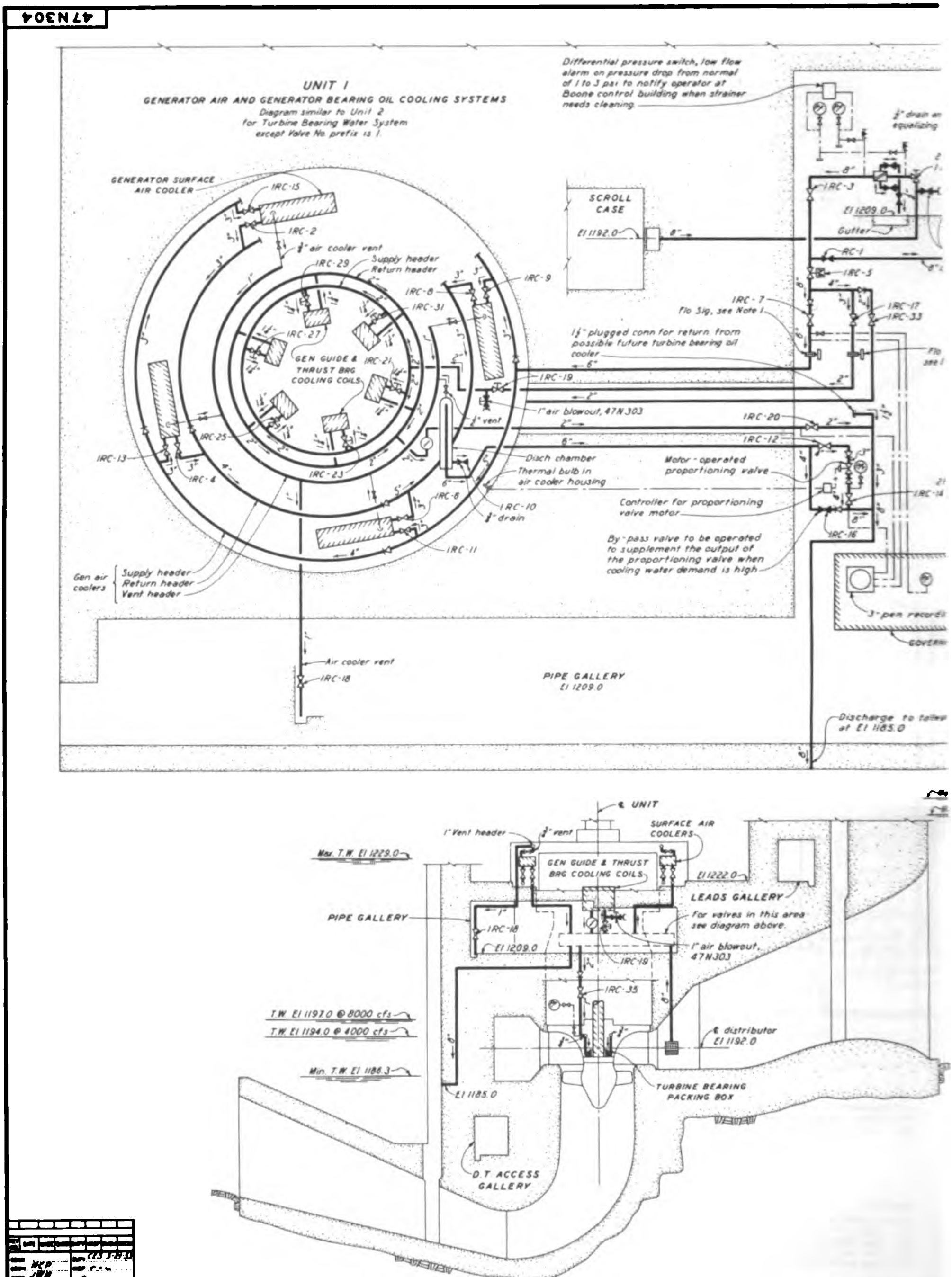
REFERENCE DRAWINGS:
47BM300 BILL OF MATERIAL - VALVE MARKER TAGS
47N300 VALVE OPERATION DIAGRAM - SYMBOLS & INDEX

POWERHOUSE
SERVICE BAY & CONTROL BLDG

VALVE OPERATION DIAGRAM
RAW WATER SYSTEM

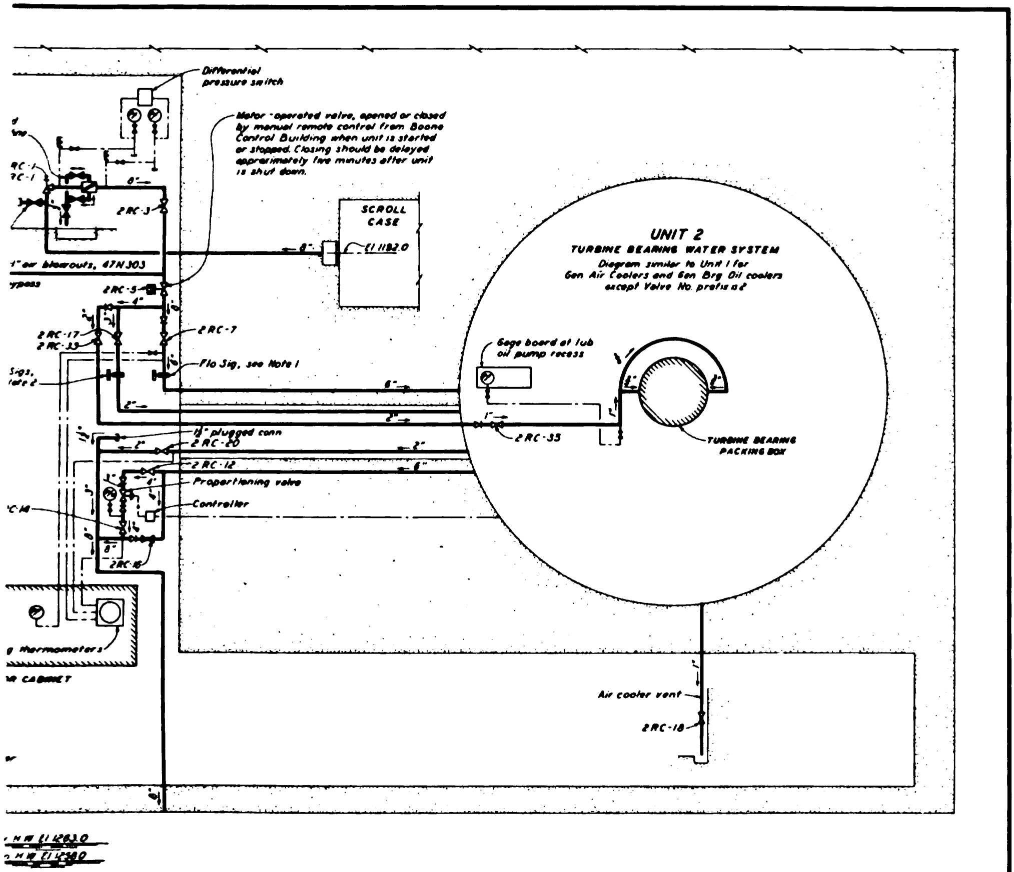
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED | RECOMMENDED | APPROVED
KNOXVILLE 12-18-41 47N302R1



TYPICAL SECTION ON ℄ UNIT

Valve numbers shown are for Unit 1 only



NOTES:

1. GENERATOR AIR COOLER FLO SIG
   One contact sounds alarm at Boone control building on low flow.
2. GENERATOR BEARING COOLING WATER FLO SIG
   Two low flow contacts:
   One contact prevents starting or shuts down unit on low flow. Other contact sounds alarm at Boone control building.

REFERENCE DRAWINGS:

47BM 300... BILL OF MATERIAL - VALVE MARKER TAGS
47N300.....VALVE OPERATION DIAGRAM - SYMBOLS & INDEX

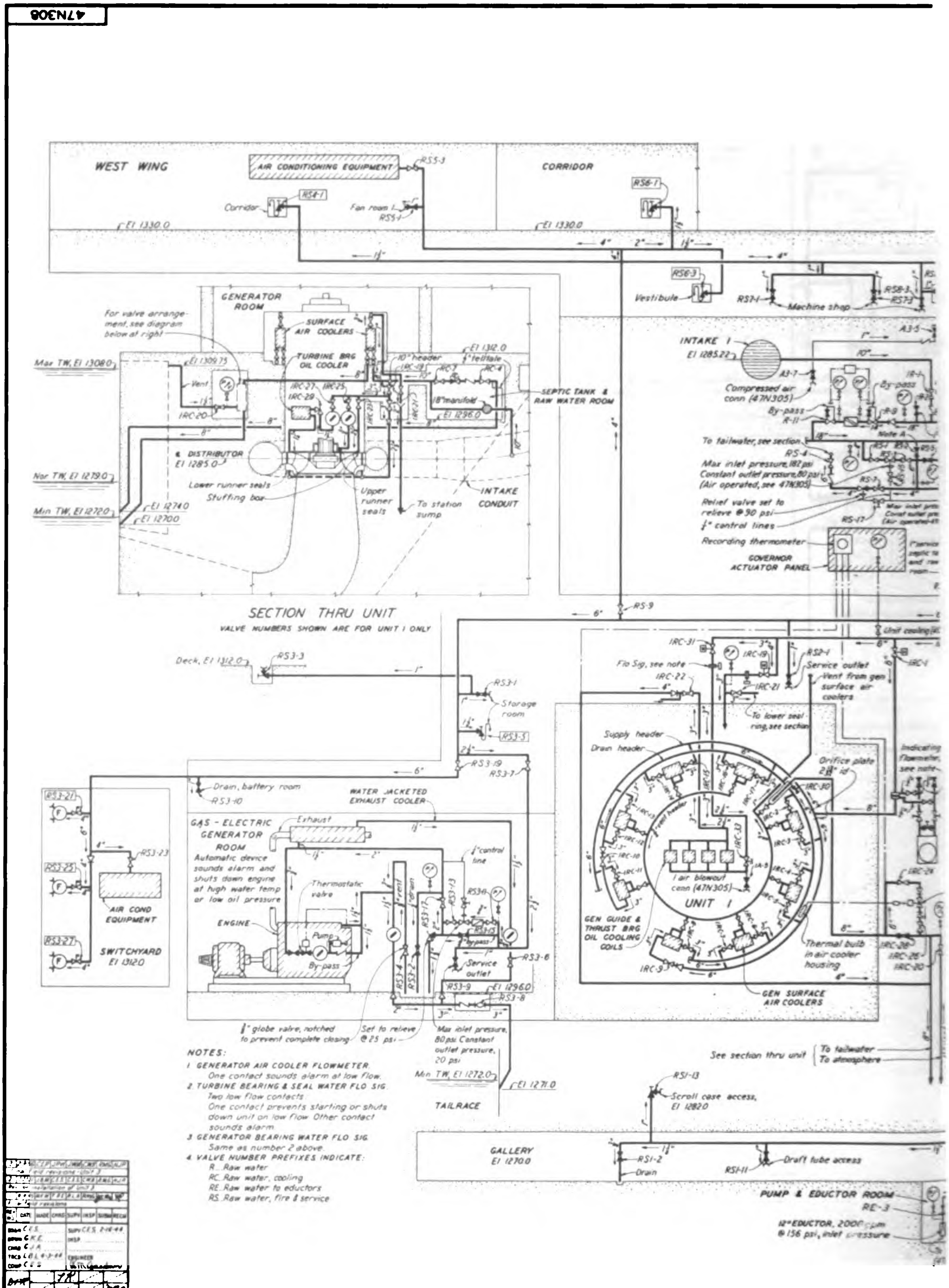
MAXIMUM RAW WATER REQUIREMENTS	
Gen surface air coolers with 77° F water temperature, per unit	490 gpm
Gen bearing oil cooling coils with 77° F water temperature, per unit	35 gpm
Turbine bearing, per unit	75 gpm

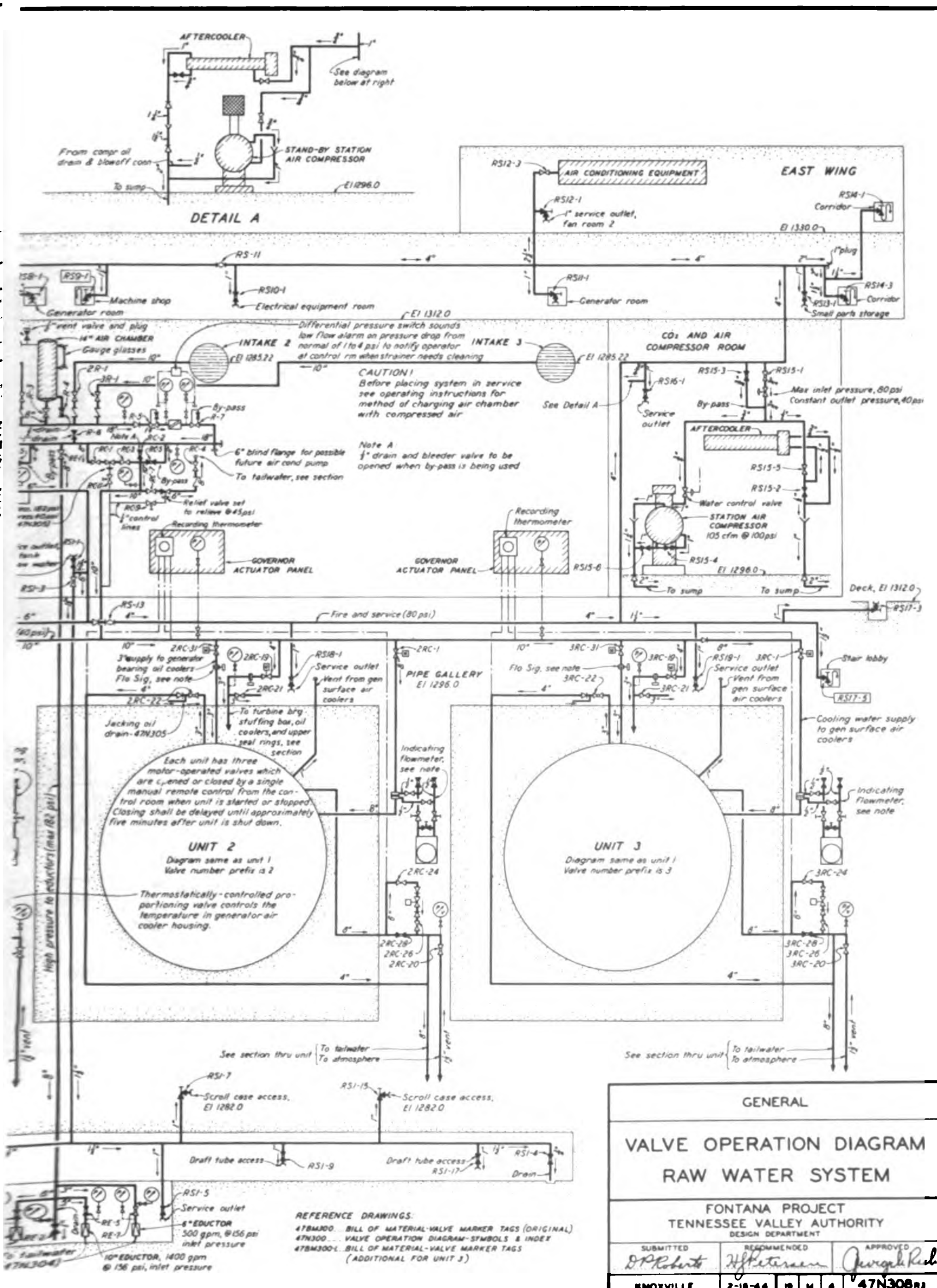
POWERHOUSE
UNITS 1 & 2

VALVE OPERATION DIAGRAM
RAW WATER SYSTEM
UNIT COOLING

FORT PATRICK HENRY PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
R M Ganan	H Petersen	R A Monroe
KNOXVILLE	9-4-53	32 M 4 47N304 R0


47N308
WEST WING
AIR CONDITIONING EQUIPMENT
CORRIDOR
GENERATOR ROOM
SURFACE AIR COOLERS
TURBINE BRG OIL COOLER
SEPTIC TANK & RAW WATER ROOM
INTAKE CONDUIT
INTAKE 1
El 1285.22
Compressed air conn (47N305)
Max inlet pressure, 182 psi
Constant outlet pressure, 80 psi
(Air operated, see 47N305)
Relief valve set to relieve @ 90 psi
1/4" control lines
Recording thermometer
GOVERNOR ACTUATOR PANEL
SECTION THRU UNIT
VALVE NUMBERS SHOWN ARE FOR UNIT 1 ONLY
Deck, El 1312.0
Storage room
Drain, battery room
WATER JACKETED EXHAUST COOLER
GAS - ELECTRIC GENERATOR ROOM
Automatic device sounds alarm and shuts down engine at high water temp or low oil pressure
ENGINE
AIR COND EQUIPMENT
SWITCHYARD
El 1312.0
Supply header
Drain header
Orifice plate
Indicating flowmeter, see note
UNIT 1
1 air blowout conn (47N305)
GEN GUIDE & THRUST BRG OIL COOLING COILS
Thermal bulb in air cooler housing
GEN SURFACE AIR COOLERS
1/2" globe valve, notched to prevent complete closing
Set to relieve @ 25 psi
Max inlet pressure, 80 psi Constant outlet pressure, 20 psi
Min TW, El 1272.0
El 1271.0
TAILRACE
See section thru unit
To tailwater
To atmosphere
Scroll case access, El 1282.0
GALLERY
El 1270.0
Draft tube access
PUMP & EDUCTOR ROOM
12" EDUCTOR, 2000 gpm @ 156 psi, inlet pressure
NOTES:
1 GENERATOR AIR COOLER FLOWMETER. One contact sounds alarm at low flow.
2 TURBINE BEARING & SEAL WATER FLO SIG. Two low flow contacts. One contact prevents starting or shuts down unit on low flow. Other contact sounds alarm.
3 GENERATOR BEARING WATER FLO SIG. Same as number 2 above.
4 VALVE NUMBER PREFIXES INDICATE: R Raw water, RC Raw water, cooling, RE Raw water to eductors, RS Raw water, fire & service



REFERENCE DRAWINGS:
47BM300 ... BILL OF MATERIAL-VALVE MARKER TAGS (ORIGINAL)
47N300 ... VALVE OPERATION DIAGRAM-SYMBOLS & INDEX
47BM300-1 ... BILL OF MATERIAL-VALVE MARKER TAGS (ADDITIONAL FOR UNIT 3)

GENERAL

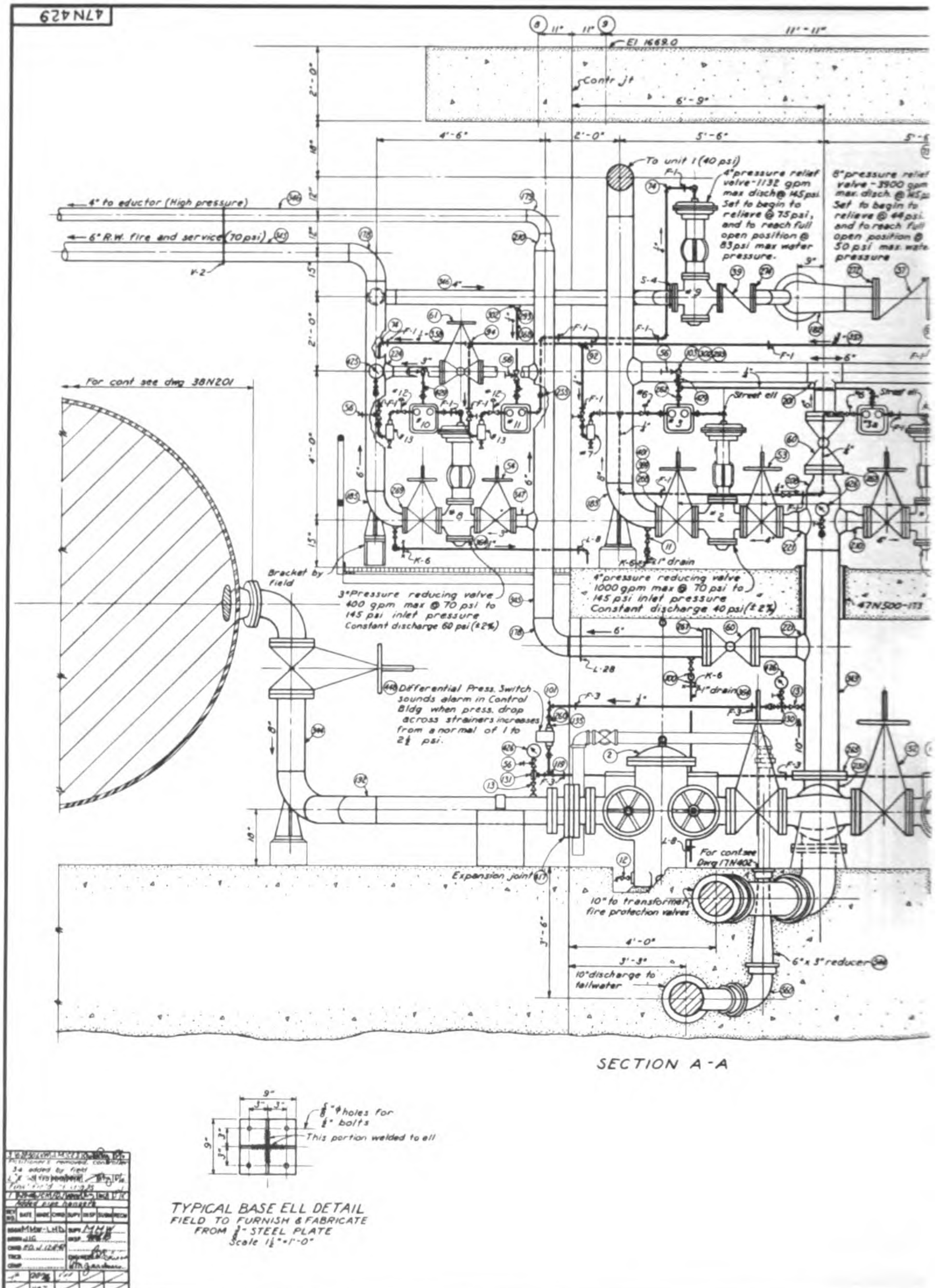
VALVE OPERATION DIAGRAM
RAW WATER SYSTEM

FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
D.P. Roberts	H.J. Petersen	George R. Rich

KNOXVILLE	2-18-44	19	M	4	47N308R3

PLATE 22


47N429
El 1669.0
Contr jt
To unit 1 (40 psi)
4" pressure relief valve-1132 gpm max disch @ 145 psi. Set to begin to relieve @ 75 psi, and to reach full open position @ 83 psi max water pressure.
8" pressure relief valve-3900 gpm max disch @ 145 psi. Set to begin to relieve @ 44 psi and to reach full open position @ 50 psi max water pressure
4" to eductor (High pressure)
6" R.W. fire and service (70 psi)
For cont see dwg 38N201
Street ell
Bracket by field
3" Pressure reducing valve 400 gpm max @ 70 psi to 145 psi inlet pressure Constant discharge 60 psi (±2%)
4" pressure reducing valve 1000 gpm max @ 70 psi to 145 psi inlet pressure Constant discharge 40 psi (±2%)
47N500-173
Differential Press. Switch sounds alarm in Control Bldg when press. drop across strainers increases from a normal of 1 to 2½ psi.
1" drain
For cont see Dwg 17N402
Expansion joint
10" to transformer fire protection valves
6" x 3" reducer
10" discharge to tailwater
SECTION A-A
⅝" φ holes for ½" bolts
This portion welded to ell
TYPICAL BASE ELL DETAIL
FIELD TO FURNISH & FABRICATE
FROM ⅜" STEEL PLATE
Scale 1½" = 1'-0"
Added pipe hangers

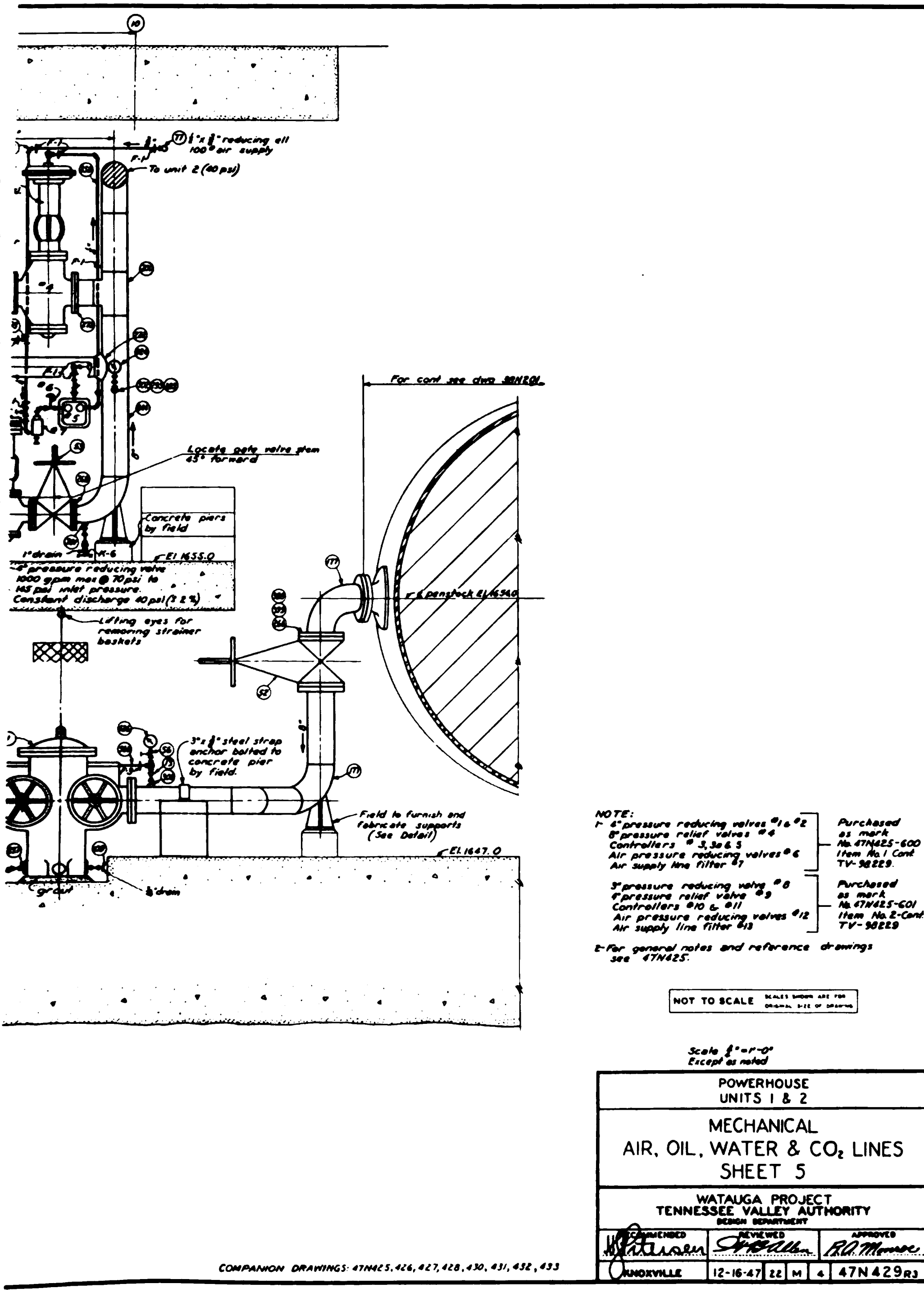

To unit 2 (40 psi)
100° air supply
Locate gate valve stem 45° forward
Concrete piers by field
El 1655.0
1" drain
6" pressure reducing valve 1000 gpm max @ 70 psi to 145 psi inlet pressure. Constant discharge 40 psi (± 2%)
Lifting eyes for removing strainer baskets
For cont see dwg
penstock
3"x ½" steel strap anchor bolted to concrete pier by field.
Field to furnish and fabricate supports (See Detail)
El 1647.0
grout
½" drain
NOTE:
1- 6" pressure reducing valves #1 & #2
8" pressure relief valves #4
Controllers # 3, 3a & 5
Air pressure reducing valves # 6
Air supply line filter #7
Purchased as mark No. 47N425-600 Item No. 1 Cont. TV-98229.
3" pressure reducing valve #8
4" pressure relief valve #9
Controllers #10 & #11
Air pressure reducing valves #12
Air supply line filter #13
Purchased as mark No. 47N425-601 Item No. 2-Cont. TV-98229
2- For general notes and reference drawings see 47N425.
NOT TO SCALE
Scale ⅜"=1'-0" Except as noted
POWERHOUSE
UNITS 1 & 2
MECHANICAL
AIR, OIL, WATER & CO2 LINES
SHEET 5
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
RECOMMENDED
REVIEWED
APPROVED
KNOXVILLE
12-16-47
47N429R3
COMPANION DRAWINGS: 47N425, 426, 427, 428, 430, 431, 432, 433

PLATE 23

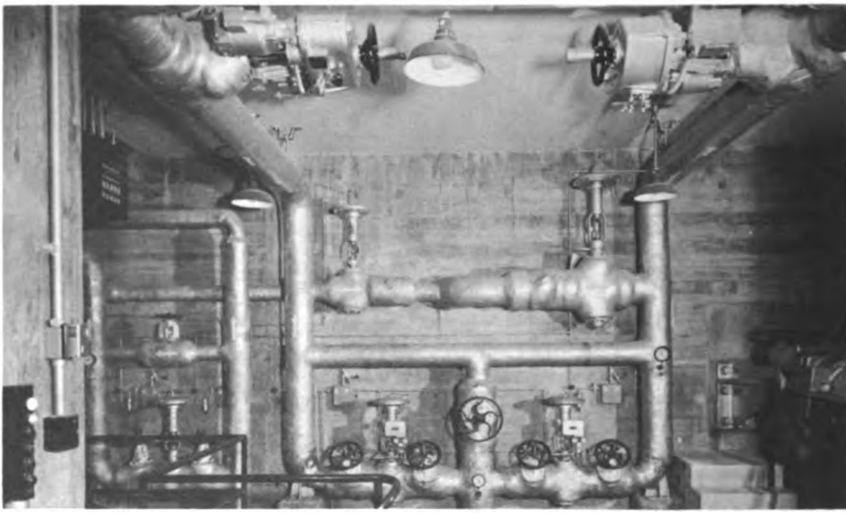


FIGURE 215.—*Raw water pressure regulating station—Watauga.*

UNIT COOLING AND LUBRICATION

Raw water for unit cooling and lubrication separates into three branches from the main supply. These are the supplies to the generator air coolers, to the generator bearing oil coolers or cooling coils, and to the turbine.

Normally, the unit cooling and lubricating water supply is opened when the unit is started and closed at a specified time interval after the unit is stopped. This is effected by opening or closing the correct valves in a gravity flow system, or by starting or stopping the cooling water pump in a pumping system. At remotely controlled plants, or plants with facilities for remote control of various equipment features, which have gravity flow cooling, motor-operated valves are stopped or started by manual remote control from the control rooms. South Holston, Watauga, Wilbur unit 4, Fort Patrick Henry, Boone, Norris, Hiwassee, Ocoee No. 3, Chatuge, and Nottely have one motor-operated valve in the main cooling water supply line to each unit. Figure 216 shows the main water supply motor-operated valve at Ocoee No. 3. At Fontana, Cherokee, and Douglas where remote control equipment was installed upon the addition of their final units, separate motor-operated valves were installed in the individual supply lines to the generator air coolers, to the generator bearing oil coolers, and to the turbine. Individual valves were necessary because of the nature of the original piping layouts. All three valves at each unit are opened or closed by a single manual remote control switch in the control room.

Temperature and pressure indication

Thermometer bulbs are installed in the cooling water supply to and return from the generator air coolers, and in the cooling water return from the generator bearing oil coolers. They are connected by capillary tubing to a three-pen temperature recorder on the

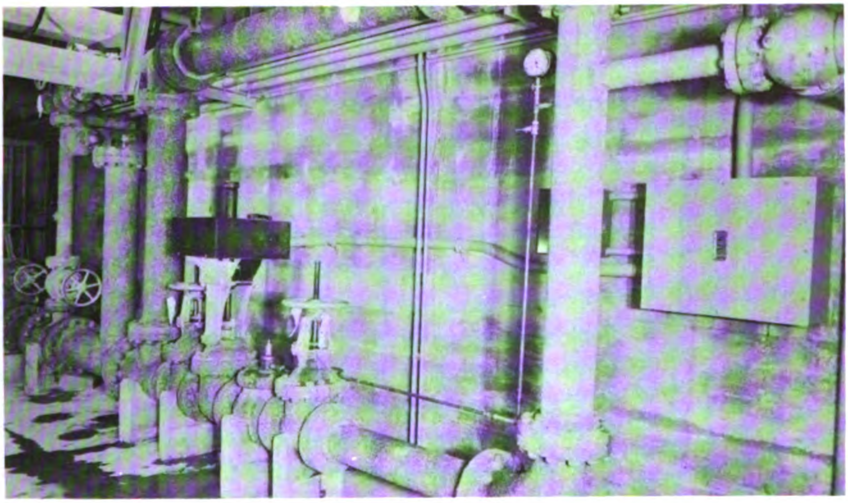


FIGURE 216.—*Main cooling water supply motor-operated valve—Ocoee No. 3.*

governor actuator panel. There is also a pressure line from the unit cooling water supply which terminates at an indicating pressure gauge on the actuator panel. This line is most frequently taken from the cooling water supply to the air coolers. On some of the plants having water-lubricated turbine bearings a pressure line was run from the turbine bearing water supply to an indicating pressure gauge on the actuator panel.

Generator cooling

The generator air coolers, usually 6 to 12 in number, are heat exchangers located in the generator air housings which employ raw water to cool circulating air which in turn cools the generator. Cooling water is delivered to a circulator header serving all air coolers. This header is sized by the generator manufacturer to distribute approximately equal flow to each cooler. From the air cooler water returns via another circular header to a discharge chamber (figure 217) designed to keep the air coolers full of water at all times. This is effected by setting the elevation of the discharge pipe from the cooler, inside the discharge chamber, equal to or above the elevation of the top of the coolers. Some of the older plants were not equipped with discharge chambers which necessitated special operating precautions. The discharge chamber and all the air coolers are vented to a common header which directs trapped air or water, if there is enough pressure in the air coolers, to a gutter in the pipe gallery. At Fontana this line runs to the station sump, but an open funnel was provided in the pipe gallery for possible future or test use. Hiwassee is the only plant where the air coolers are vented upward to atmosphere with no provision for flow observation.

TVA furnishes piping to the air-coolers supply header and from the air coolers return header. Piping between these points, except for a portion of the vent piping, is furnished by the generator manufacturer.

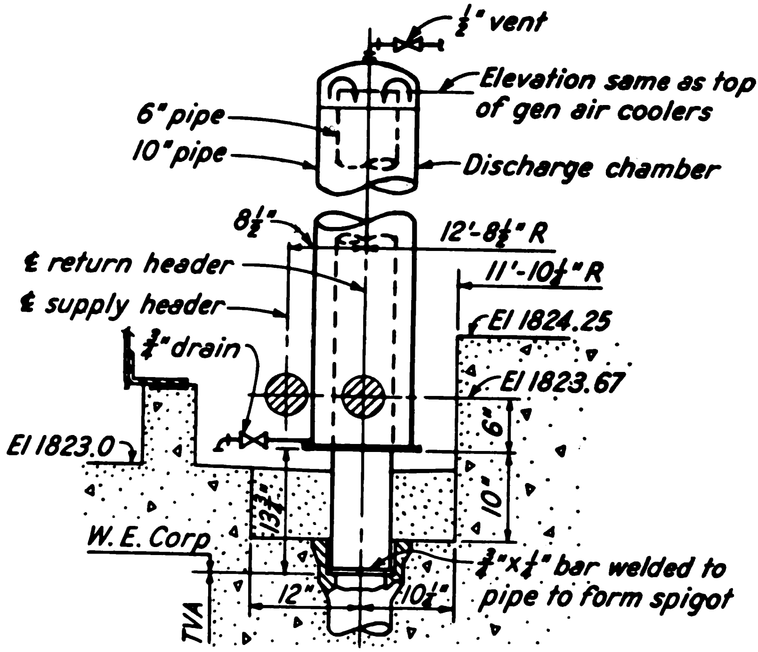


FIGURE 217.—*Generator air cooling water discharge chamber.*

Cooling water flow through the air coolers must be carefully controlled in order to effectively cool the air without overdoing it to the extent that condensate forms in the stator windings. In the older plants discharge valves were manually throttled to control flow. Control is automatic in all new plants and most old plants have been converted or are in the process of being converted to automatic control. With automatic control, water from the coolers is directed through a proportioning valve (fig. 218) which throttles the flow in proportion to the temperature in the generator housing. This valve is controlled by a thermostat actuated by a temperature sensitive bulk mounted in the generator air housing. It is positioned by an electric-motor or air-motor-operated valve positioner which maintains a constant generator air temperature with varying temperature and pressure of the cooling water, and varying heat output of the generator. At a few plants a mechanical stop was provided on the proportioning valve to prevent full valve closure, ensuring some flow at all times, but this feature is no longer considered necessary in the latest designs.

When proportioning values were first used by TVA they were sized to pass the maximum anticipated flow. This caused considerable squealing, chattering, and damage to the valve seats due to the closeness of and excessive contact between inner valves and seats during cold raw water periods when limited quantities were required for adequate cooling. At the present time the proportioning valve is sized to pass at least one-half of the maximum anticipated flow, with a bypass sized to handle the total flow required at maximum flow conditions. During warm water periods when the cooling water demand exceeds the capacity of the proportioning valve, the

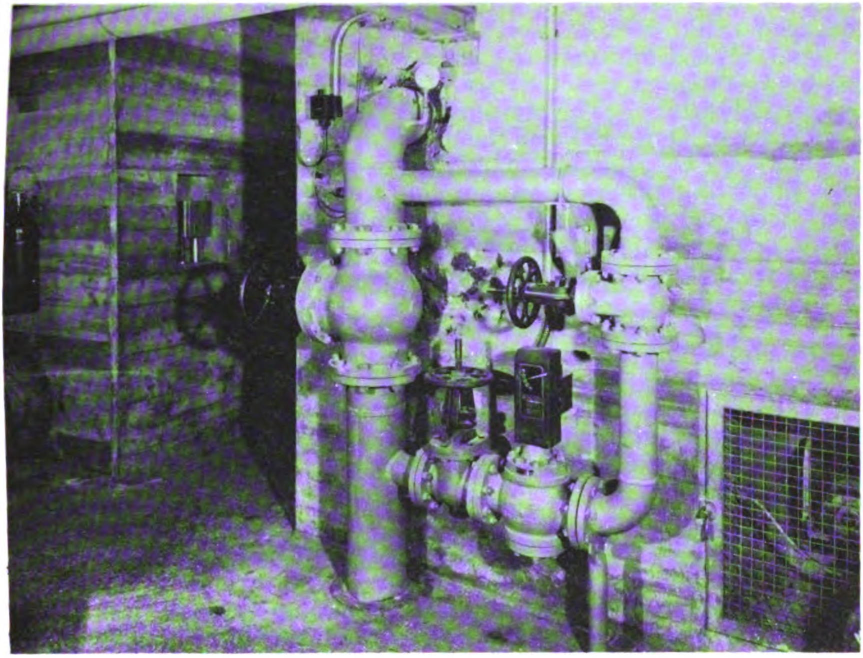


FIGURE 218.—*Thermostatically controlled proportioning valve in cooling water discharge from generator air coolers—Cherokee.*

bypass valve is partially opened to augment its capacity. At Ocoee No. 3 the proportioning valve and bypass are located ahead of the air coolers.

Lubricating oil in the generator guide and thrust bearing reservoir is cooled by raw water circulating through coils or other type tube coolers. A connection for air blowout, consisting of a valve and universal hose coupling, is provided for clearing coils or coolers. On some generators there is a blowout connection for each cooler, while on others one connection serves all coolers. The generator manufacturer has in many instances provided lock shield valves at these connections, but this is not always done since they are rather inaccessible and possibility of misoperation is negligible.

Normally a flow sight, furnished by the generator manufacturer, is installed in the bearing cooling water return line. Fort Loudoun, Kentucky, and Hiwassee have two flow sights, one for each bank of two coolers per generator.

Indicating flowmeters are placed in the cooling water supply lines to the generator air coolers and to the generator bearing oil coolers. The flowmeter in the bearing waterline is equipped with two electrical contacts set to close on low flow. One contact effects annunciation, the other prevents starting or shuts down the unit. The flowmeter in the air cooler line has the alarm contact only. For a time the flowmeters on the air cooler supply were of the orifice type (fig. 219). Their use was abandoned in favor of a meter in use on some generator bearing waterlines, which is operated by the flow of water acting on a swinging gate. This was done primarily be-

cause at the time of the change the swinging-gate-type meter came equipped with heavier electrical contacts. This flowmeter also causes less head loss than the orifice meter and is very sensitive in the lower range, a characteristic which is exactly opposite to that of a fixed orifice. The swinging-gate-type meter, shown in the lower part of figure 220, has the disadvantage of not actually metering flow, but only giving an indication of flow magnitude. Vane-type indicating meters shown in the upper part of figure 220 are sometimes used for small flows of 50 gallons per minute and less.

Piping for the generator bearing oil coolers is furnished by TVA to and from the pit. Continuation inside is by the generator manufacturer.

In low head plants it is convenient to discharge raw water from the generator air coolers and bearing oil coolers to the scroll case. In high head installations this would result in reversal of flow since the water in the scroll case is under much higher pressure than the discharge from the generator air coolers and bearing oil coolers. For this reason this discharge is piped to tailwater in high head plants.

Turbine bearing lubrication, cooling, and seals

In most plants the raw water supply to the turbine branches off the unit cooling water supply after passing through the main strainer. In plants having water-lubricated bearings it branches off ahead of the main strainer and passes through a separate strainer furnished by the turbine manufacturer. This strainer has a finer basket mesh for added protection of the water-lubricated bearing. A provision is made for interconnection with the unit cooling water supply, however. At Guntersville it was necessary to filter the turbine bearing water after the injurious effect to the bearings of raw river water with high silt content was discovered. Here, raw water is drawn from the forebay, strained, and passed through one

FIGURE 219.—*Orifice type flowmeters in cooling water supply to generator air coolers and generator bearing oil coolers—Guntersville.*

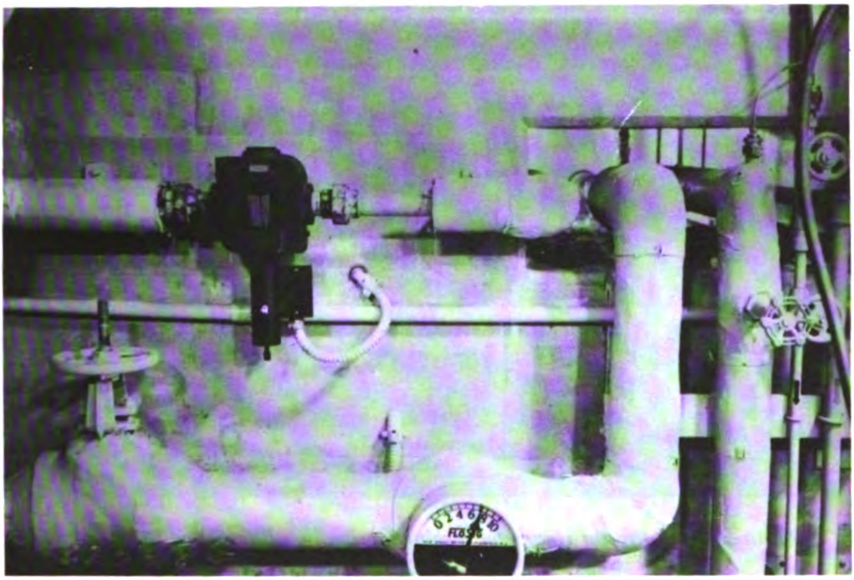


FIGURE 220.—*Swinging gate type meter (bottom) in water supply to turbine guide bearing and runner seals with vane-type indicating meter (above) in water supply to generator bearing oil coolers—Chatuge.*

of three pressure sand filters (fig. 221) before it goes to the turbine bearing.

All Kaplan-type turbines, with the exception of Fort Patrick Henry, are provided with water-lubricated guide bearings. Finely strained raw water passes through the bearing, lubricating it, and then discharges to the draft tube just above the runner hub.

In those turbines employing oil for bearing lubrication, water is used where necessary for cooling the oil in a multiple pass heat exchanger. The discharge is normally piped to tailwater. At Chatuge and Nottely, where grease is the bearing lubricant, water is circulated through a baffled cooler around the bearing, and discharged through the runner to the draft tube.

Francis turbines require lubricating water for the upper runner seal and sometimes for the lower runner seal, depending on whether or not the seal is positioned to get adequate lubrication from water passing through the runner. All turbines require a small amount of water for lubricating the packing in the stuffing box.

An indicating flowmeter of the swinging-gate type with two electrical contacts is placed in the main turbine water supply line or in the bearing lubricating water supply line. One contact effects annunciation. The other shuts down the unit and prevents starting. Sight flows are often furnished by the turbine manufacturer. They are usually in the supply line to the runner seals.

Piping is furnished by TVA to the inside of the turbine pit where it is continued by the turbine manufacturer to the point of application.

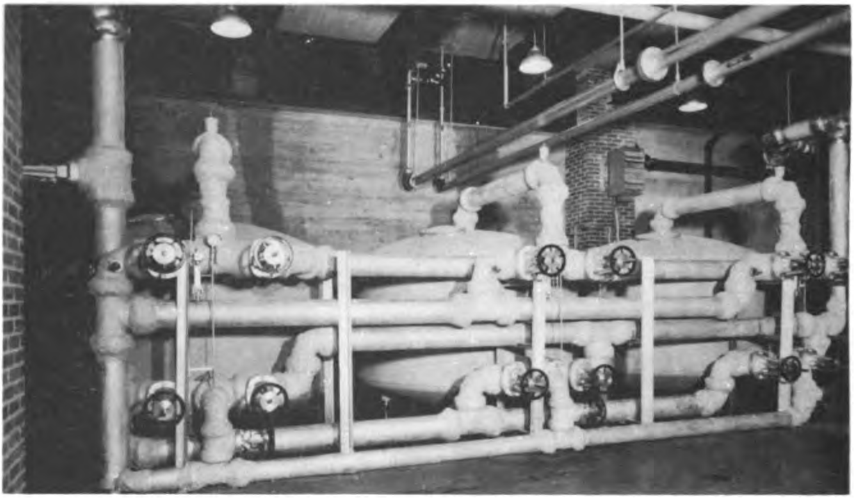


FIGURE 221.—*Pressure filters for turbine bearing water supply—Guntersville.*

MISCELLANEOUS USES

Raw water is provided for cooling cylinder jackets and cylinder heads of water-cooled air compressors. Control is usually by a pneumatic valve actuated through the pneumatic control system of the compressor. When the unit is unloaded, air pressure forces the valve's diaphragm down. This cuts off the main water flow allowing only a trickle of water through a bypass, ensuring against overheating the machine. When the compressor loads, pressure is released from the diaphragm allowing full flow. This valve can be adjusted to keep the discharge temperature around 100° F., preventing injurious condensate from forming inside the cylinder walls.

Cooling water is also furnished to the compressor aftercooler. In the aftercooler air passes through tubes, and cooling water flows through baffles over the outside of the tube nest. Flow is controlled by a manually operated globe valve. Condensate is no problem and flow is continuous.

Raw water is used for condensing in the refrigeration machinery for air conditioning in many plants. Some air-conditioning systems were designed to allow the refrigeration machinery to be bypassed by raw water from the reservoir for use in the cooling coils when the water temperature is sufficiently low. At Norris raw water at 40° to 50° F. is circulated through a central cooling coil to provide air cooling for the reception room, office, and control room. Air for the generator room is cooled by a surface cooler through which raw water is circulated.

In a few of the higher head plants raw water is used for operating eductors. At Fontana raw water at full headwater pressure, ranging from 112- to 196-pound-per-square-inch static pressure at the eductors, is used to operate three eductors. A 6-inch eductor is used to discharge station drainage aided by a standby pump. One 10-inch and one 12-inch eductor are provided to handle draft tube

unwatering, in some instances aided by a portable pump. Ocoee No. 3, Apalachia, Watauga, Norris, and Hiwassee also use eductors in conjunction with pumps.

At those plants where gasoline-electric generators are provided for auxiliary power, raw water is used for cooling the engine and its exhaust. Gasoline-electric generators are fully described in chapter 5.

Raw water is used for powerhouse and switchyard fire protection and for lawn sprinkling in small plants or where the treated water supply is inadequate for fire protection.

PUMPS

Where required, electric-motor-driven pumps are installed to boost the pressure of the water through the unit cooling system. Separate pumps, similar in construction to the unit cooling water pumps, are used for normal fire and service water pumping, fire-protection booster service, and emergency cooling water service.

The capacities of the pumps installed in the hydro plants are given in table 8, page 436.

Pumps for unit cooling water service are usually specified as 1,800-revolution-per-minute, horizontal, single-stage, centrifugal pumps direct-connected to the motor through a flexible coupling. The design capacities range between 1,100 and 1,300 gallons per minute with design heads varying from 30 to 50 feet. The maximum efficiency of the pump is specified to be as near the design head as feasible and the shutoff head is specified to be materially greater than the design head. Flat characteristic performance curves are preferred with the head remaining constant as the capacity varies. The operating characteristics of the pump and the rated capacity of its motor are specified to be such that the motor shall not exceed its rated temperature rise or name plate horsepower capacity when operating under any head condition between shutoff and the minimum specified.

Pump casings are usually horizontally split with flanged suction and discharge openings integral with the lower half of the casing. Renewable wearing rings are specified for all casings.

Impellers are bronze and of the enclosed type. Renewable impeller wearing rings are specified for all pumps larger than 4-inch size.

Pump shafts are of forged or heat-treated, high carbon or alloy steel, ground and polished, and protected by removable bronze or alloy steel wearing sleeves fastened to the shaft and extending through the stuffing box. Pump bearings are specified to be of the ball, roller, or ring oiling plain type enclosed in splashproof housings.

Motors for unit cooling water pumps as described above range in capacity from 15 to 25 horsepower. They are generally squirrel cage, 440 volts, 3 phase, 60 cycles, normal torque, low starting current, NEMA Design B, for full voltage start with dripproof frames. Temperature rise is limited to 50° C. above an ambient of 40° C. Routine tests only are required for motors of this capacity.

Smaller pumps ranging in capacities up to 600 gallons per minute for fire protection and other raw water services are generally spe-

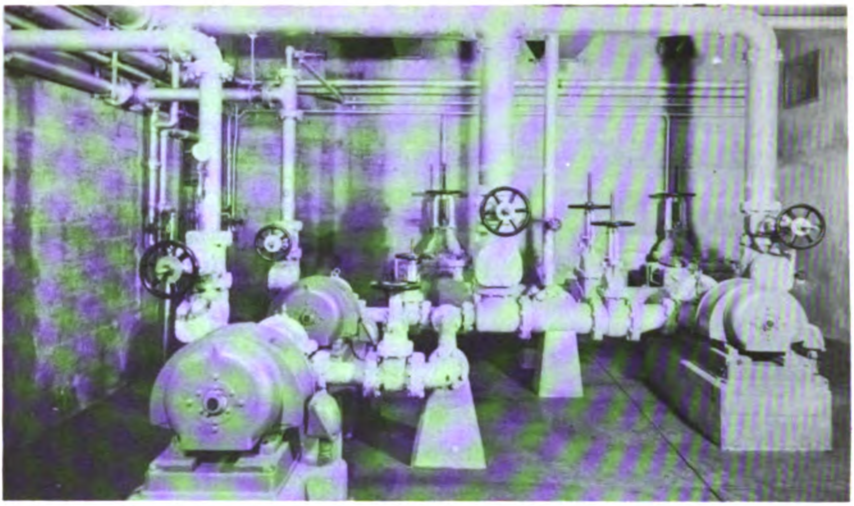


FIGURE 222.—*Fire and service water pumps (left) and emergency unit cooling water pump (right)—Chickamauga.*

cified to be of the close coupled, end suction type, with speeds up to 3,600 revolutions per minute. The design heads of such pumps range up to 250 feet. Casings on units of this type are vertically split to facilitate removal of the impeller. Casing wearing rings are required, but impellers are generally furnished without wearing rings for these smaller-size units. Figure 222 shows the fire and service water pumps, and the emergency cooling water pump in the Chickamauga plant. Detailed specifications covering pumps are included in appendix B. Figure 223 shows a typical unit cooling water pump arrangement of the Guntersville project.

STRAINERS

Twin- or multiple-basket-type strainers (fig. 224) are used on all raw water supply lines. These strainers are arranged so that one basket can be cleaned without interrupting service. The baskets are usually steel with 3/16- or 1/8-inch perforations. The housings for low-pressure strainers are cast iron while housings of strainers in high head plants are cast steel. Pressure taps go from each side of the strainer to a differential pressure switch which causes an alarm when there is an abnormal pressure drop across the strainer, indicating that it needs cleaning.

PIPING

Cast-iron bell and spigot pipe and fittings are used for all embedded raw water piping of 3 inches or larger. Black wrought-iron ASTM A 72 pipe and screwed black malleable iron fittings are used for embedded piping sizes below 3 inches.

Black steel ASTM A 120 pipe is generally used for exposed raw water piping; however, in wet or damp areas or above suspended ceilings, galvanized wrought iron may be utilized due to its longer

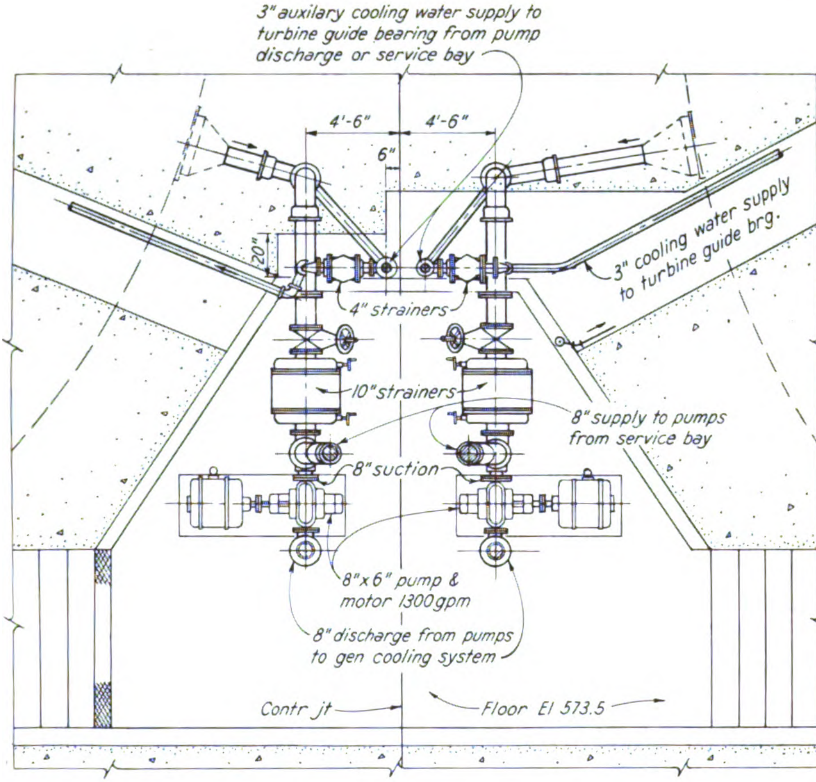


FIGURE 223.—*Typical unit cooling water pump arrangement—Guntersville.*

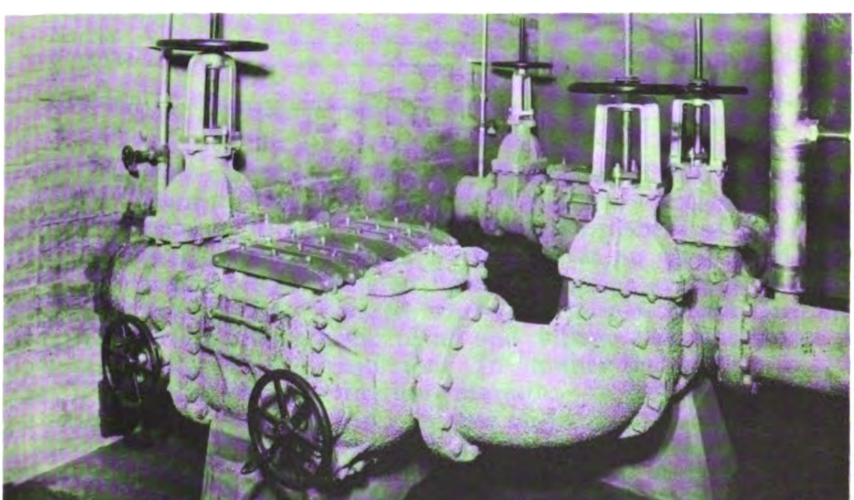


FIGURE 224.—*Raw water strainers—Chickamauga.*

lasting quality. Normally, $\frac{1}{4}$- through $2\frac{1}{2}$-inch fittings are screwed malleable iron. From 3 inches up, black steel welding fittings are normally used, with cast-iron flanged fittings utilized where desirable. Slip-on welding forged steel flanges are used on this low-pressure-type service. In most instances, special cast-iron flange and spigot pipe is used in the transition of large raw water lines from the embedded to the exposed position, or up to the first cutoff valve in the system.

Large gate and check valves are IBBM type, with smaller valves being of bronze construction of gate or globe pattern, depending upon the valve function.

CHAPTER 9

TREATED WATER SYSTEMS

Treated water is provided at all TVA hydro power stations for drinking water and at all but two for all sanitary purposes. Compared to most public water supplies, the quantity required is very small and yet the quality of water furnished must meet State health department requirements. Accepted methods of treatment and sterilization are therefore necessary, but because of the small size of the plants the cost of treatment is relatively high. For this reason, whenever practical, treated water is purchased from a nearby city system or other State-approved source. The following TVA hydro stations purchase all treated water from such sources, as shown:

Hydro station	*Treated water source*
Chickamauga	Chattanooga, Tenn.
Fort Loudoun	Lenoir City, Tenn.
Fort Patrick Henry	Kingsport, Tenn.
South Holston	Bristol, Tenn.
Blue Ridge	U.S. Forest Service, Blue Ridge, Ga.

Another somewhat similar method is to obtain treated water from the original water-treatment plants built by TVA for the construction forces and the construction camps, and which treatment plants have since been purchased or leased by private or public interests. The three hydro stations where this is done and their sources of treated water are as follows:

Hydro station	*Treated water source*
Norris	Town of Norris, Tenn.
Fontana	Government Services, Inc., Fontana Village, N.C.
Kentucky	Kentucky State Park Service, Kentucky Village, Ky.

At Kentucky one of the conditions of transfer of the village and treatment plant to the state was that TVA was entitled to water without charge up to half the capacity of the plant. At the other two projects TVA pays for the water used at an established rate and as determined by a metered flow. A similar arrangement existed for a few years at Hiwassee where the State of North Carolina operated the water-treatment plant and village but this plant is now back under TVA jurisdiction. In another instance, at Watts Bar, TVA sells water to private interests. In this case the construction village was leased to a private organization as a resort and TVA sells metered quantities of water from its treatment plant in the powerhouse to this resort at established rates. Figures 225 and 226 show the water treatment plants at Hiwassee, Kentucky, and Fontana while figure 227 shows interior views of the Fontana plant.

Figure 225.—*Water treatment plants—Hiwassee (top) and Kentucky (bottom).*

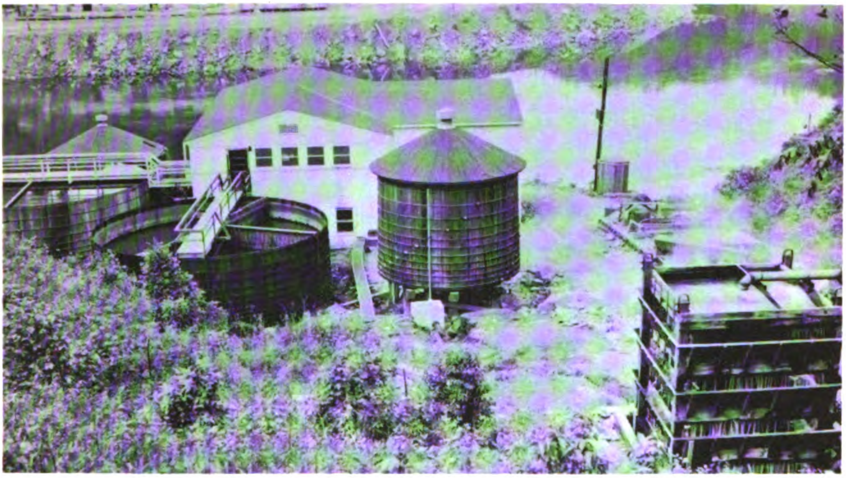


FIGURE 226.—*Water treatment plant (aerator at right)—Fontana.*

On the Wilson Reservation, the Division of Chemical Engineering operates the water-treatment plant and sells water to the several other TVA divisions, including the hydro plant, the steam plant, Division of Reservoir Properties, Division of Agricultural Relations, and also to a U.S. Army plant which is on the reservation.

TVA also furnishes water to the Army Engineers, who operate the navigation locks at each one of the main-river dams. This water is for sanitary purposes only and is used by operators and visitors.

At two of the hydro plants which TVA purchased from private power companies, bottled drinking water is furnished and raw water used for all other sanitary purposes. These plants are Wilbur and Nolichucky. Both are small and have no facilities for visitors.

SOURCE OF SUPPLY

For the raw water supply to its treatment plants TVA tries to find a nearby spring or develop a well. These sources usually furnish clear water requiring no other treatment than chlorination. Unfortunately, only a few of these sources which were dependable throughout the year have been found and the majority of the supplies are obtained from the lakes formed by the hydro plant dams. The water from Watauga Lake is of such high quality that chlorination is the only treatment. The water from all other lakes is subject to varying degrees of pollution and turbidity. Complete treatment including filtration and chlorination is, therefore, provided at all other plants obtaining raw water from the lakes. Table 9 presents data concerning water supply source, method of treatment, and other pertinent information for each of the hydro plants listed.

WATER TREATMENT

The design drawings for all water supplies, treatment plants, and distribution systems are submitted to the appropriate State health department for approval. Although TVA is not legally bound to

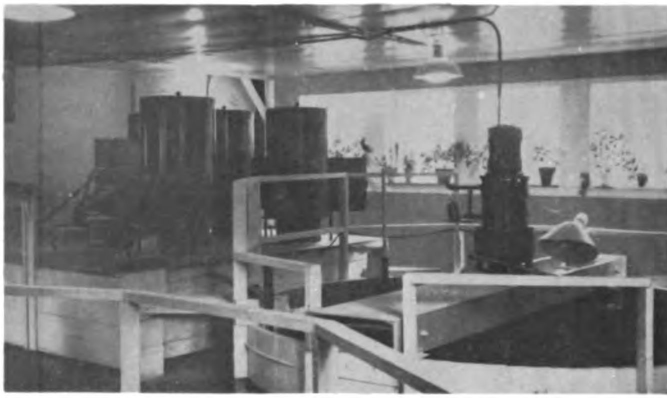


FIGURE 227.—*Interior views of Fontana water-treatment plant—flocculator (top), chemical feeders (center), and chlorinators (bottom).*

Table 9.—*Treated water supply data*

Project	Supplied by	Source	Type of treatment for TVA-constructed plants	Treatment plant capacity GPM	Treated water storage in gallons: Clearwell	Treated water storage in gallons: Elevated
Norris	Town of Norris, Tenn.	Springs	Chlorination	[1] 250		250,000
Wheeler	TVA	Tennessee River	Coagulation, gravity filtration, and chlorination.	70	25,000	25,000
Pickwick	do	Wells	Aeration, sand filtration, and chlorination	150	1,700	50,000
Guntersville	do	Springs	Chlorination	[4] 120		100,000
Chickamauga	Chattanooga, Tenn.	Tennessee River				
Hiwassee	TVA	Hiwassee River	Coagulation, gravity filtration, and chlorination.	125	9,000	50,000
Watts Bar	do	Tennessee River	do	100	13,185	100,000
Wilson	Chemical Plant	do				
Cherokee	TVA	Mills Spring	Coagulation, pressure filtration, and chlorination.	150		50,000
Douglas	do	Springs	Chlorination	[1] 85		50,000
Ocoee No. 1 [5]	do	do	do	[4] 40		2,500
Ocoee No. 2 [5]	do	Big Creek	Slow sand filtration and chlorination	2	2,000	[2, 3] 128
Ocoee No. 3	do	Gassoway Creek	Coagulation, pressure filtration, and chlorination.	10		[2, 3] 476
Apalachia	do	Hiwassee River	do	20	2,100	1,000
Fort Loudoun	Lenoir City, Tenn.	Tennessee River				
Kentucky	Kentucky State Park Service	Wells	Aeration, coagulation, gravity filtration, and chlorination.	200	20,000	100,000
Fontana	Government Services, Inc.	Little Tennessee River	Aeration, sand filtration, and chlorination	700	48,650	21,000
Watauga	TVA	Watauga River	Chlorination	[4] 10		1,655
Wilbur	do	Bottled				
South Holston	Bristol, Tenn.	Holston River (South Fork)				
Hales Bar	TVA	Tennessee River	Coagulation, gravity filtration, and chlorination.	125	20,000	23,000
Boone	do	Holston River (South Fork)	do	10	740	[2] 448
Fort Patrick Henry	Kingsport, Tenn.	do				
Chatuge	TVA	Wells	Chlorination	[4] 4.1		220
Nottely	do	do	do	[4] 3.17		220

[1] Minimum recorded flow from spring.
[2] Working capacity.
[3] Hydropneumatic storage tank.
[4] Pump capacity.
[5] Acquired plants included due to rehabilitation of domestic water system.

do this, it has done so in all cases as a matter of policy. These drawings are submitted to the state through TVA's Division of Health and Safety. This division is responsible for the quality of water produced by these plants from a health standpoint and later receives operating reports and suggests changes in treatment and degrees of sterilization in order to maintain safe health standards. An operator visits all plants at least once a day to inspect the operation, replenish chemicals, make chemical analyses, wash the filters, and clean the settling basins when necessary, and do other work required for the proper operation of the plant. Residual chlorine tests are determined daily at all plants and, where necessary for control of floc formation, water stabilization and softening, the related requisite tests are also made. Daily records of all tests, pumpage, and remarks on operation are sent once a month through TVA's Division of Health and Safety to the board of health of the State in which the plant is located. Operating instructions are prepared by the Mechanical Design Branch and provided to the operating personnel in charge of the water-treatment plants. Operating instructions for the Boone water-treatment plant are included in appendix E.

A brief description of the following four types of plants used by TVA is given starting below: The conventional gravity rapid sand filter plant at Watts Bar; the pressure filter plant at Apalachia; the chlorinating plant for spring water at Douglas; and the slow sand filter plant at Ocoee No. 2. For brief descriptions of water supplies at other hydro plants refer to chapter 2.

Watts Bar hydro plant

This plant is the largest water-treatment unit TVA has within a hydro powerhouse. The construction activities were served from a temporary rapid sand gravity filter plant which was subsequently transferred to the Hales Bar project for a permanent water supply. The permanent plant in the powerhouse has a rated capacity of 100 gallons per minute and serves the hydro and steam plants, control building, lock and switchyard with both sanitary and fire-protection water. The plant is located on two levels in the powerhouse service bay. It consists of lime and alum dry chemical feeders, mixing chamber, settling basin, two gravity rapid sand filters, two chlorinators, clearwell, one wash water and two service pumps, and elevated storage. Figure 228 shows a schematic flow diagram of this plant and figure 229 is a view of the plant at the operating floor level.

Raw water is obtained from the forebay through any one of three intakes located at different elevations in the upstream face of the service bay bulkhead. The operator is thus able to select water from whichever stratum of lake water is most easily treated. The raw water flows by gravity through a rate controller to the mixing chamber where it is agitated by a motor-operated vertical shaft paddle wheel mixer, and coagulating chemicals are added. Provision is made at the venturi meter for prechlorination if found necessary. The mixing chamber provides a theoretical retention time of 30 minutes.

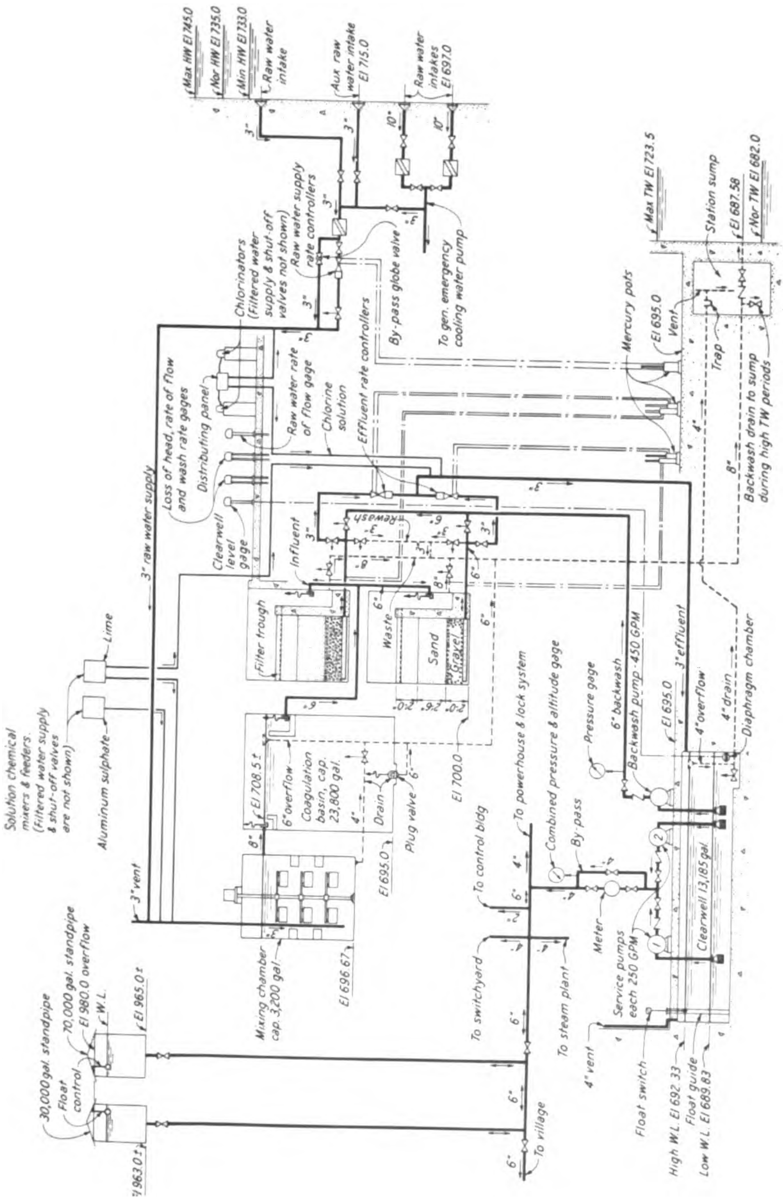


FIGURE 228.—*Flow diagram of rapid sand gravity filtration water-treatment plant—Watts Bar.*

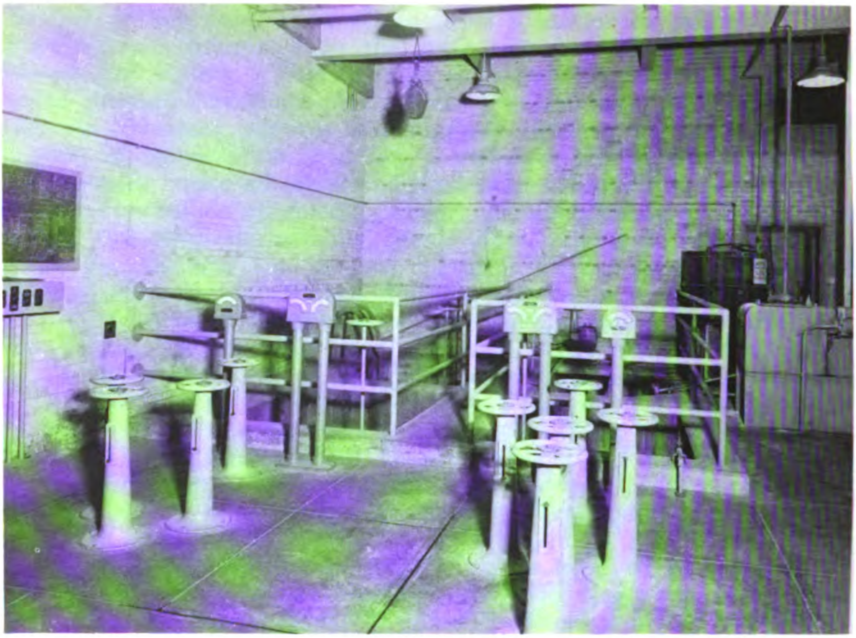


FIGURE 229.—*Operating floor of rapid and gravity filter type water treatment plant—Watts Bar.*

Water flows by gravity from the mixing chamber through the settling basin to the filters. The settling basin is the straight-through type with weir-type distributor and collector at either end. The basin provides a theoretical retention period of 4 hours. The basin is cleaned by draining it to the powerhouse sump.

The filters are conventional gravity rapid sand units designed for a rate of 2 gallons per square foot of surface area per minute and made up of filter sand and graded gravel layers, drained by a perforated pipe collector system. The rate of flow through the filters is controlled by a rate-of-flow controller on the effluent of each filter, as illustrated in figure 230. Loss-of-head, rate-of-flow, wash rate, raw water rate-of-flow, and clearwell level gages are provided. The filters are washed by a wash water pump having a capacity of 450 gallons per minute at 35-foot head. Wash water flows by gravity to the powerhouse sump.

Controlled flow from the filters flows by gravity to the 13,185-gallon-capacity concrete clearwell located in the base slab of the service bay floor. The water is chlorinated immediately following the rate controllers. Figure 231 shows a view of the chlorinators.

On the slabs over the clearwell are mounted the wash water pump and two high head service pumps. The latter pump the water into the distribution system and to storage. An integrating water meter measures the output of the plant. A view of these pumps is shown in figure 232.

The entire plant is designed for automatic operation with the exception of washing the filters. Under automatic operation the service pumps are controlled by float switches in the elevated storage

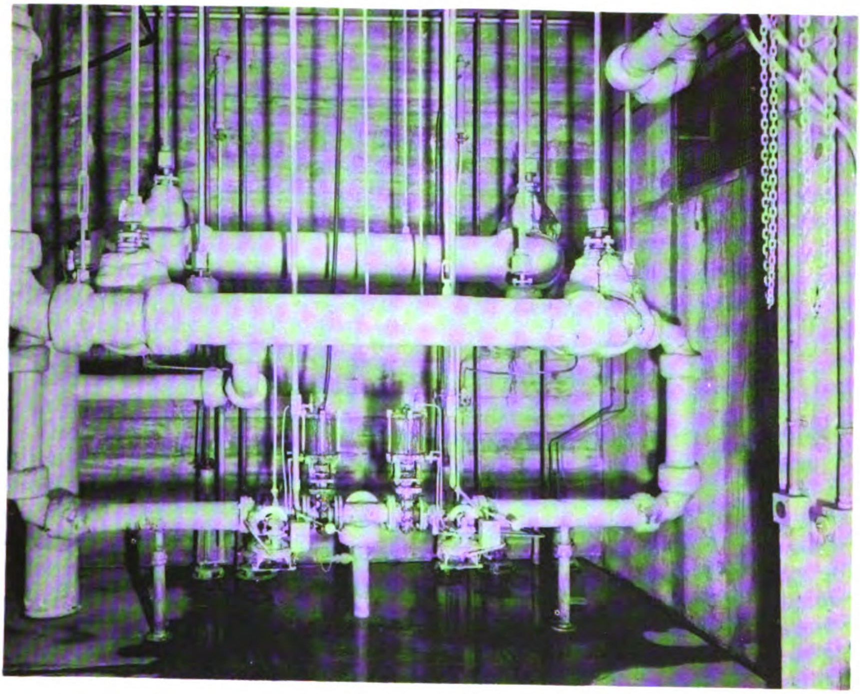


FIGURE 230.—*Filter rate controllers—Watts Bar.*

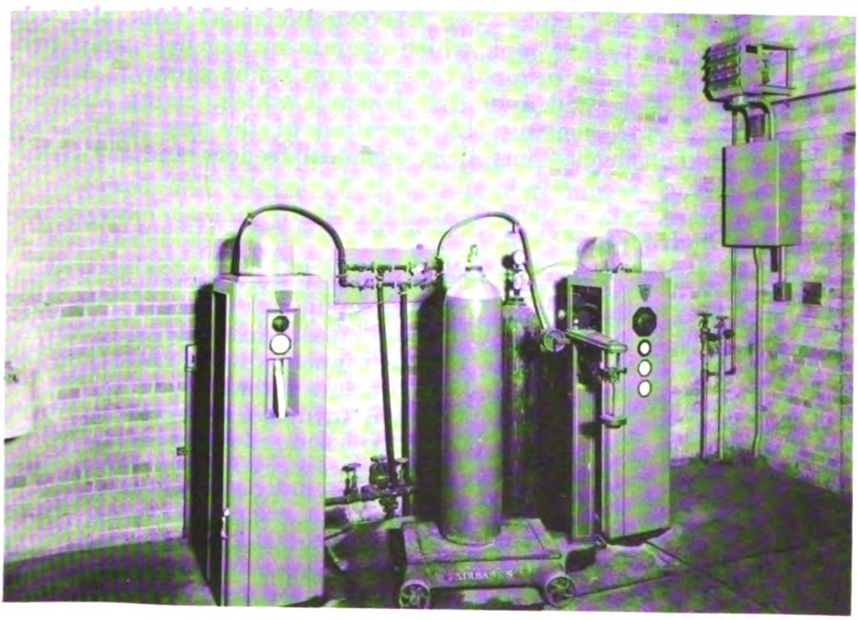


FIGURE 231.—*Filter plant chlorinators—Watts Bar.*

FIGURE 232.—*Backwash pump (foreground) and service water pumps (rear)—Watts Bar*

tanks. Two elevated tanks—one 30,000-gallon steel tank and one 70,000-gallon wood stave tank which operate in parallel—were provided as a part of the original construction water survey. A float control switch is provided in the clearwell which, acting through a master contactor, controls the operation of the raw water rate controller, filter effluent controllers, chemical feeders, and the chlorinators.

Apalachia hydro plant

The construction activities at this project were served by a temporary water-treatment plant installed at Farner Camp which supplied the damsite and certain adjoining areas, while the requirements at the powerhouse and some of the tunnel adits were served by 15-gallon-per-minute, portable-type pressure filters.

The permanent water-treatment plant furnishes water for sanitary purposes in the powerhouse only. It has a rated capacity of 20 gallons per minute and is located in the service bay of the powerhouse. The plant is operated, however, at a rate of from 10 to 15 gallons per minute to carry over less floc from the coagulation tank. The plant consists of solution-type alum and soda ash feeders, a mixing chamber, upward-flow settling basin, two pressure-type filters, hypochlorite and stabilizing chemical feeders, clearwell, two service pumps, and elevated storage. Except for filter washing the plant is entirely automatic. A schematic diagram of this system is shown in plate 24.

Raw water is normally obtained from the unit penstocks with flow controlled by a solenoid valve and pressure-reduced by a pressure reducing valve. In case both penstocks are empty, water may be obtained by pumping from an intake in the tailrace by means of a centrifugal pump provided for this purpose. Rate of raw water flow is controlled by adjustment of the reducing valve. A too high flow will result in wasting water over the settling tank overflow; a too low flow will result in plant shutdown by float switch on the settling basin.

Three motor-driven hypochlorinators introduce coagulant to the system—one for alum solution, one for soda ash solution, and the other a standby for either of the others. Stone crocks are provided for storage of the solutions.

The mixing tank is of steel with "over and under" baffles giving a theoretical retention time of 25 minutes.

The settling basin is of the upward-flow type having a theoretical retention time of 4 hours and 50 minutes with very little chance of short-circuiting. Water flows by gravity from the mixing tank to a system of perforated pipes on the bottom of the tank where it is distributed evenly over the entire bottom. The water rises at a somewhat slower rate than the subsiding rate of the majority of the floc particles and is collected at the top by orifices just below the surface in a collector pipe. Sludge is removed by high velocity backflow through the bottom distributor system by means of a valved connection to the station sump.

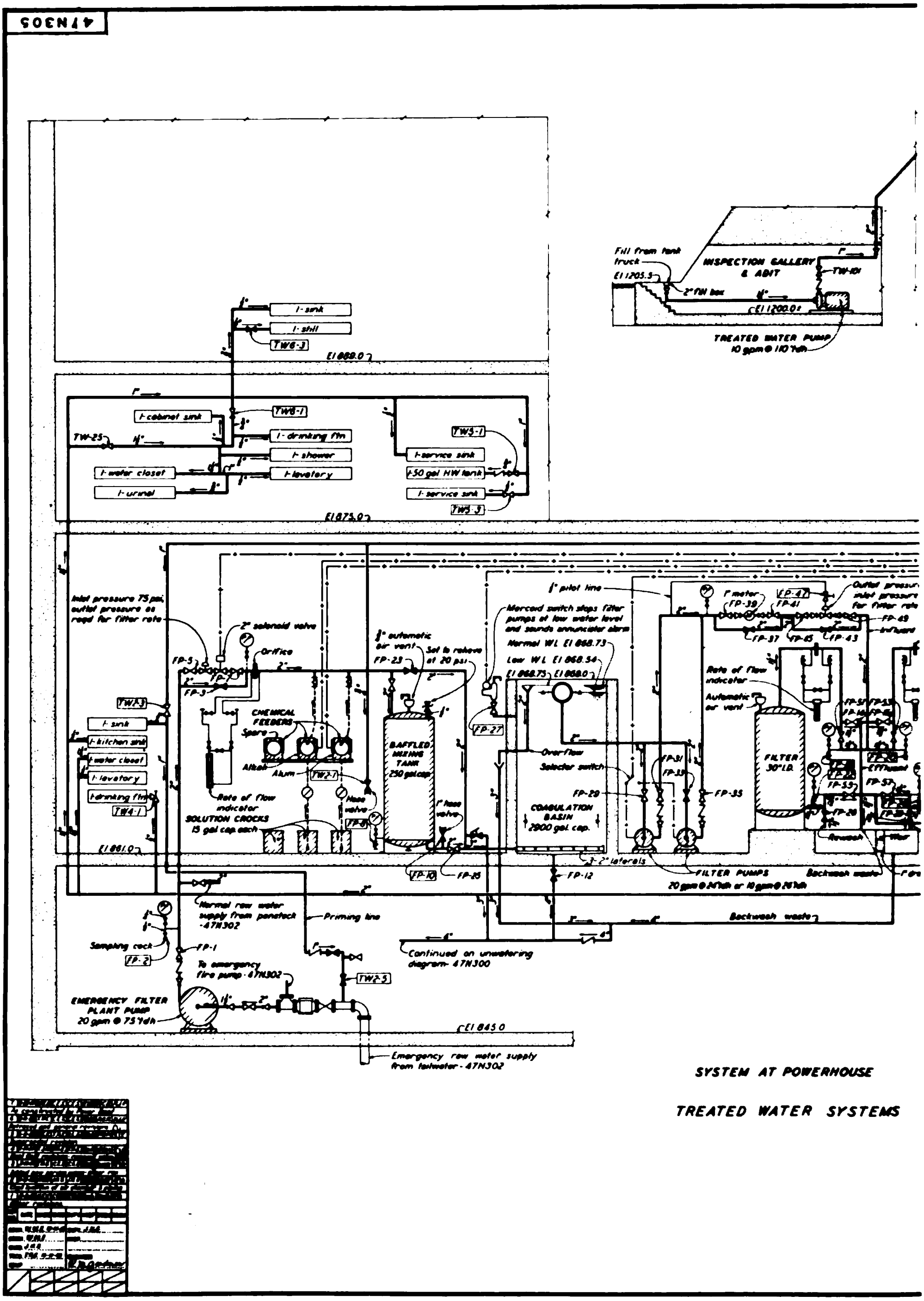
From the settling tank water flows to two pressure filters and thence to the clearwell. In order that the plant could be confined to one room on one floor a small low head centrifugal pump forces the water through the filters. The rate is controlled by maintaining a constant discharge pressure on the pump by means of a self-contained pressure control valve. This is calibrated by mercury U-tube, rate-of-flow indicators on each filter influent line. The filters are washed with water from the distribution system with pressure reduced by a lock-shield throttled globe valve. The rate of wash is observed and degree of throttling determined by reverse flow through the mercury U-tube indicator. Wash water flows by gravity to the station sump.

Hypochlorite for sterilization and either an alkali or Calgon (sodium hexametaphosphate) solution for water stabilization is introduced into the filter effluent line by two electric-motor-operated hypochlorinators. The spare coagulant feeder also acts as standby for either of these units.

The filtered water goes directly to a concrete open-top clearwell having a capacity of 2,100 gallons and located in the water-treatment room. An overflow and drain to station sump are provided.

Two 20-gallon-per-minute centrifugal motor-driven service pumps pump water from the clearwell into the powerhouse distribution system and into a 1,000-gallon tank located 200 feet higher than the clearwell in the penstock valve chamber. One service pump is controlled by float switches in this tank. The other pump is a standby unit.

Under automatic operation, when the clearwell level drops to near empty, a float switch, operating through a master contactor,



SYSTEM AT POWERHOUSE

TREATED WATER SYSTEMS

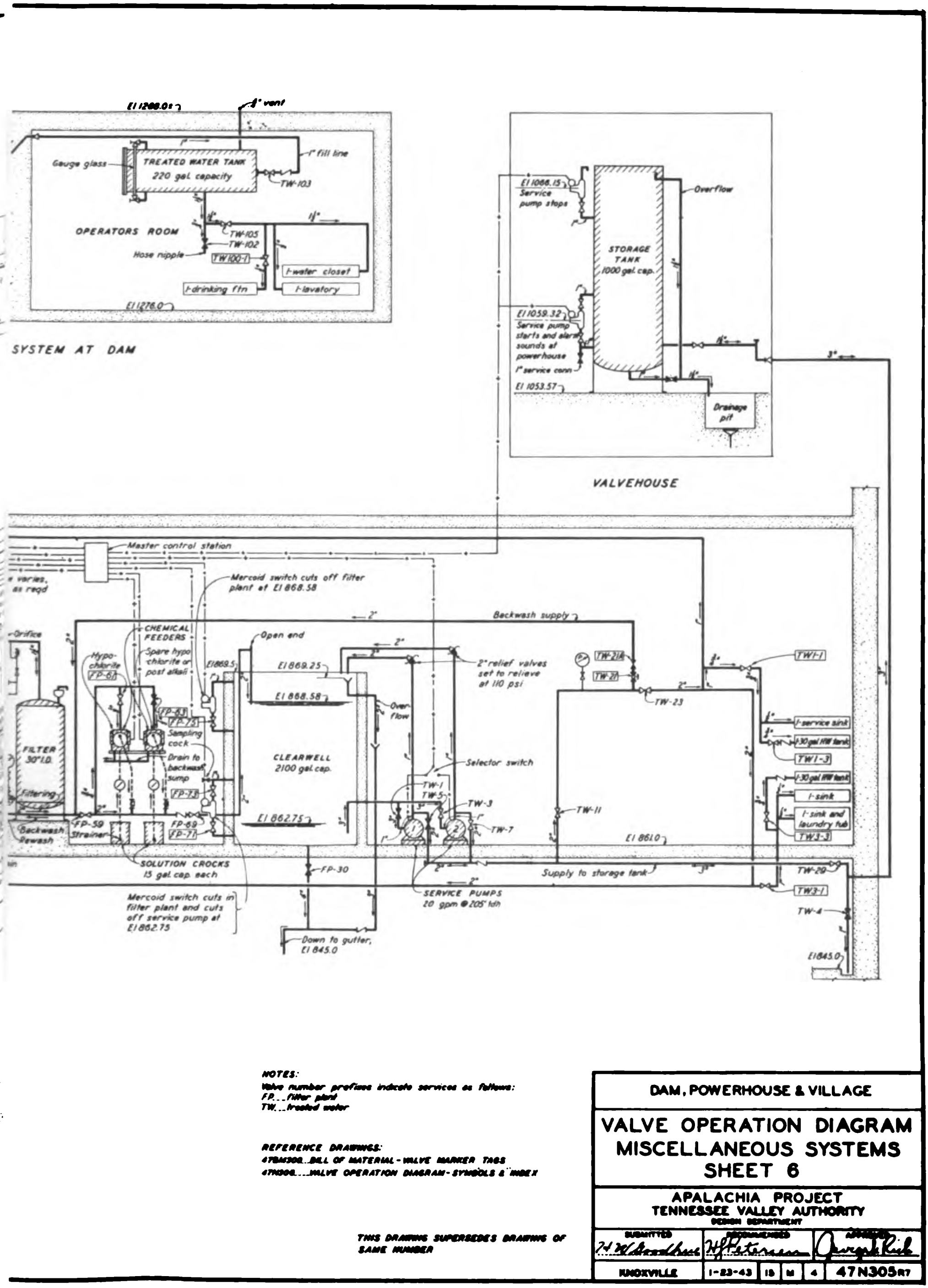

TREATED WATER TANK 220 gal. capacity
OPERATORS ROOM
SYSTEM AT DAM
STORAGE TANK 1000 gal. cap.
VALVEHOUSE
Master control station
CHEMICAL FEEDERS
CLEARWELL 2100 gal. cap.
FILTER 30" I.D.
SOLUTION CROCKS 15 gal. cap. each
SERVICE PUMPS 20 gpm @ 205' tdh
Selector switch
Supply to storage tank
Backwash supply
2" relief valves set to relieve at 110 psi
Mercoid switch cuts off filter plant at El 868.58
Mercoid switch cuts in filter plant and cuts off service pump at El 862.75
Down to gutter, El 845.0
NOTES:
Valve number prefixes indicate services as follows:
FP...filter plant
TW...treated water
REFERENCE DRAWINGS:
47BM306...BILL OF MATERIAL - VALVE MARKER TAGS
47N306....VALVE OPERATION DIAGRAM - SYMBOLS & INDEX
THIS DRAWING SUPERSEDES DRAWING OF SAME NUMBER
DAM, POWERHOUSE & VILLAGE
VALVE OPERATION DIAGRAM
MISCELLANEOUS SYSTEMS
SHEET 6
APALACHIA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
1-23-43
47N305R7

PLATE 24

stops the service pump and puts the treatment plant in operation. The master contactor causes the following units to operate: the raw water solenoid valve, the coagulant feeders, the filter pump, the hypochlorinator, and post-alkali feed. When the clearwell fills, another float switch acting through the master contactor causes these units to stop and if the elevated tank is not full to start the service pump.

The Apalachia plant was originally designed as a 20-gallon-per-minute supply to serve not only the powerhouse but also the requirements of 20 operators' and safety personnel residences, and a community building located in Smith Creek Village some 2 miles distant from and approximately 670 feet higher than the powerhouse. Two positive displacement service pumps rated 25 gallons per minute at 340 pounds per square inch furnished water from the powerhouse through a 3-inch main to a 50,000-gallon elevated steel storage tank in the village. A 350-gallon-per-minute booster pump at the base of the storage tank provided fire protection for the village. This village was operated from September 1942 to February 1946 (during World War II period), after which time it was abandoned and dismantled. During this period considerable trouble was experienced with the original two high head service pumps at the powerhouse and the pressure regulating valves which supplied the powerhouse. These pumps were horizontal, rotary, tubular-type positive displacement units which were not of sufficiently rugged construction to withstand high head water service. After many successive outages due to breaking connecting rods, pins, etc., these units were replaced with two horizontal duplex positive displacement piston-type pumping units each rated 35 gallons per minute at 790-foot total dynamic head. These units, which proved entirely satisfactory, were ultimately transferred to construction use and replaced with the present lower head pumps when the village was abandoned. Figure 233 shows a view of the treatment plant equipment as originally installed.

During the period of village operation the powerhouse sanitary water supply was initially reduced from the village pressure of 350 pounds per square inch through a single self-contained pressure regulating valve to a pressure of approximately 75 pounds per square inch. The severity of this service caused constant repairs to the reducing valve and its pop safety type relief valve. These items were subsequently replaced with two step diaphragm controlled, pneumatically actuated regulators and relief valves. The first-step regulator reduced the incoming water pressure from 350 pounds per square inch to 125 pounds per square inch and the second-step regulator provided powerhouse pressure at 60 pounds per square inch. This arrangement proved quite satisfactory until the village was abandoned and the present arrangement was adopted whereby the powerhouse is supplied by an unreduced pressure of approximately 80 pounds per square inch from the valve house storage tank.

The operators' quarters located at the dam, which is 13.5 miles upstream from the powerhouse, is provided with a 220-gallon water storage tank and a small filling pump to receive water delivered by truck from the powerhouse water-treatment plant.

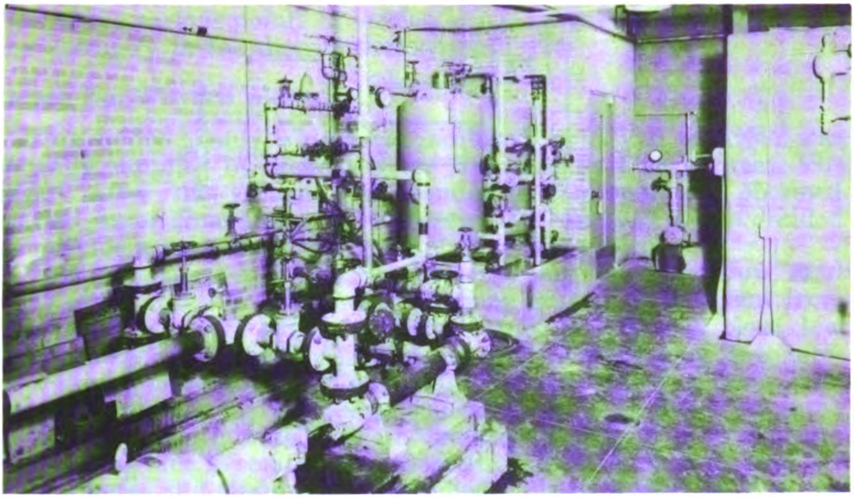


FIGURE 233.—*Interior view of pressure filter water-treatment plant prior to improvements—Apalachia.*

Douglas hydro plant

At this plant spring water is chlorinated and treated with Calgon for stabilization. No other treatment is given nor required. Water is used for sanitary and fire protection in the powerhouse, switchyard, and picnic areas. This plant also served all of the requirements of the construction activities. The plant is located on the right bank of the river about 3,500 feet from the powerhouse. Figure 234 shows a flow diagram of the water-treatment and pumping plant.

The spring has a minimum recorded flow of 85 gallons per minute. It is protected and some storage provided by a low-roofed, concrete-walled springhouse having a central-floored, high-roofed room for housing the pumps, hypochlorinators, meter, and controls. A weir-type overflow is set at approximately the original discharge elevation so as not to alter the hydraulic characteristics of the original spring setting.

Two two-stage, 60-gallon-per-minute at 345-foot head pumps take their suction directly from the spring and discharge through a 6-inch cast-iron pipe to an elevated tank above the powerhouse. Only one pump operates at a time; the other is a standby unit. Operation of the pumps is by float switch control from the elevated tank.

Three electric-motor-driven solution-type hypochlorinators are provided—one for feeding a solution of hypochlorite for sterilization, one for feeding a solution of Calgon for water stabilization, and the third a standby for either of the others. These units discharge into the pump suction line, and their motors are interconnected with the pump controls so that feeders and pump all start and stop together under automatic control.

An integrating meter on the pump discharge line measures the total output of the plant. Because of the wide variation in eleva-

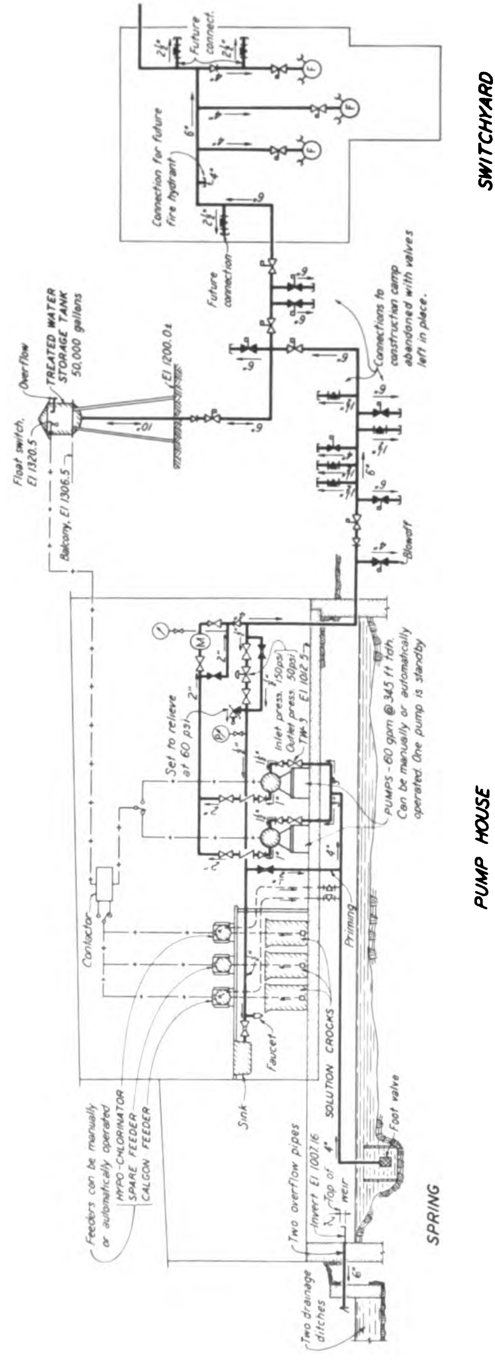


FIGURE 234.—*Flow diagram of spring supply water-treatment plant—Douglas.*

tion of the various points of service, several pressure reducing valves are necessary in the distribution system.

Ocoee No. 2 hydro plant

This hydro plant, which was acquired by TVA in 1939, was initially supplied by treated water from nearby Caney Creek Village. After the village was abandoned, the operators obtained bottled water from Ocoee No. 3 filter plant. In 1949 it was decided to provide a permanent water supply for this project.

This permanent plant is unusual in being the only slow sand filter plant of TVA. Raw water flows by gravity to the plant from Big Creek, a source which normally furnishes relatively clear, low color water. The plant consists of two filters, each having 25-square-foot area, a clearwell for filtered water storage, a service pump, two hypochlorinators, and a hydropneumatic tank. The filters are rated at 1 gallon per minute each or one-fiftieth that of a rapid sand filter. The unit is completely automatic except for replenishing the hypochlorite and cleaning the filter bed. Plates 25 and 26 illustrate this small plant.

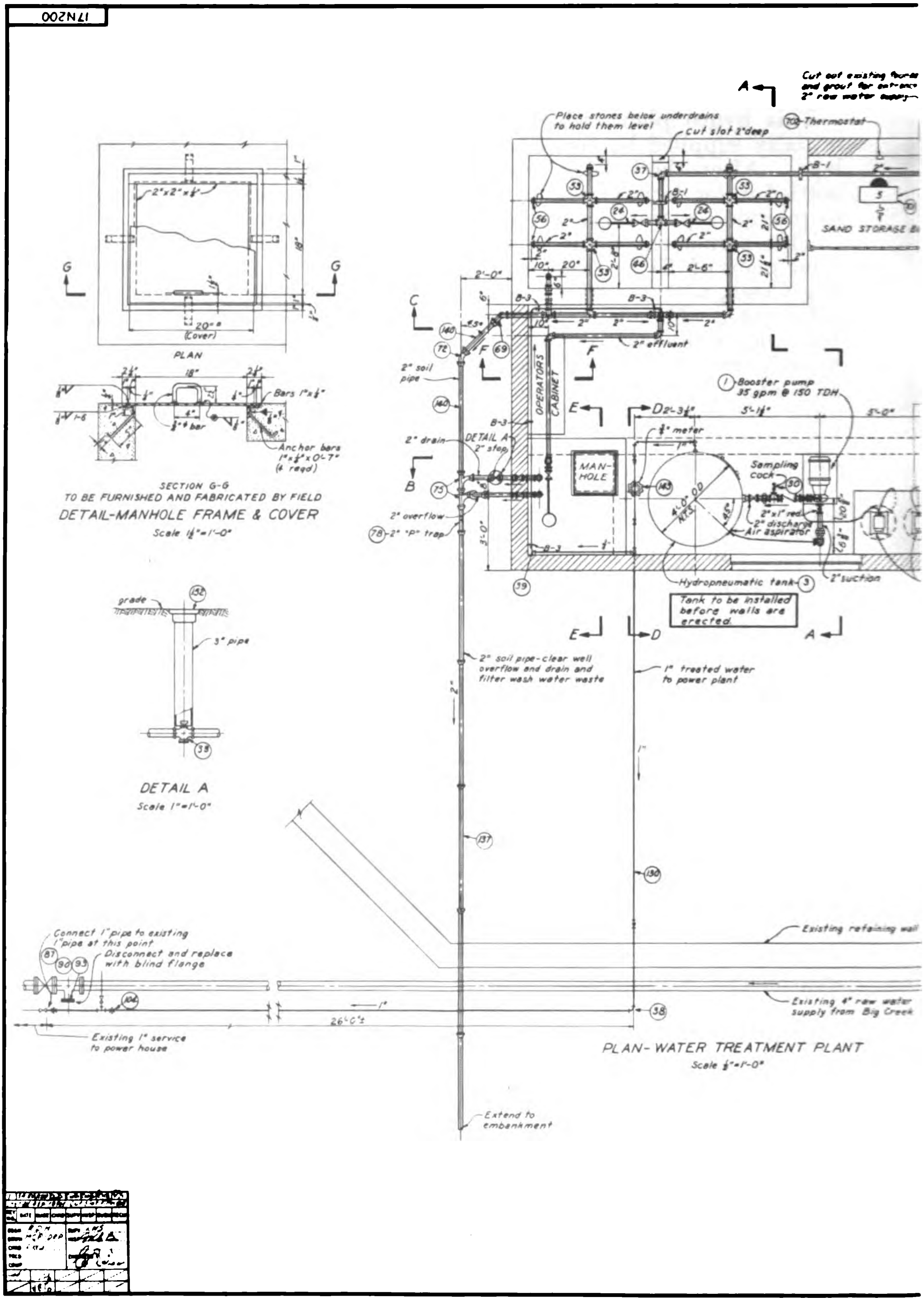
The gravity flow of raw water to the filter is controlled by balanced float valves operated by the level of water in the equally divided filter beds. The rate of flow through the filter is regulated by a vented siphon effluent pipe between the perforated pipe underdrains and the clearwell. The vented siphon limits the head causing flow to 2 inches. An overflow is provided in both the filter and the clearwell.

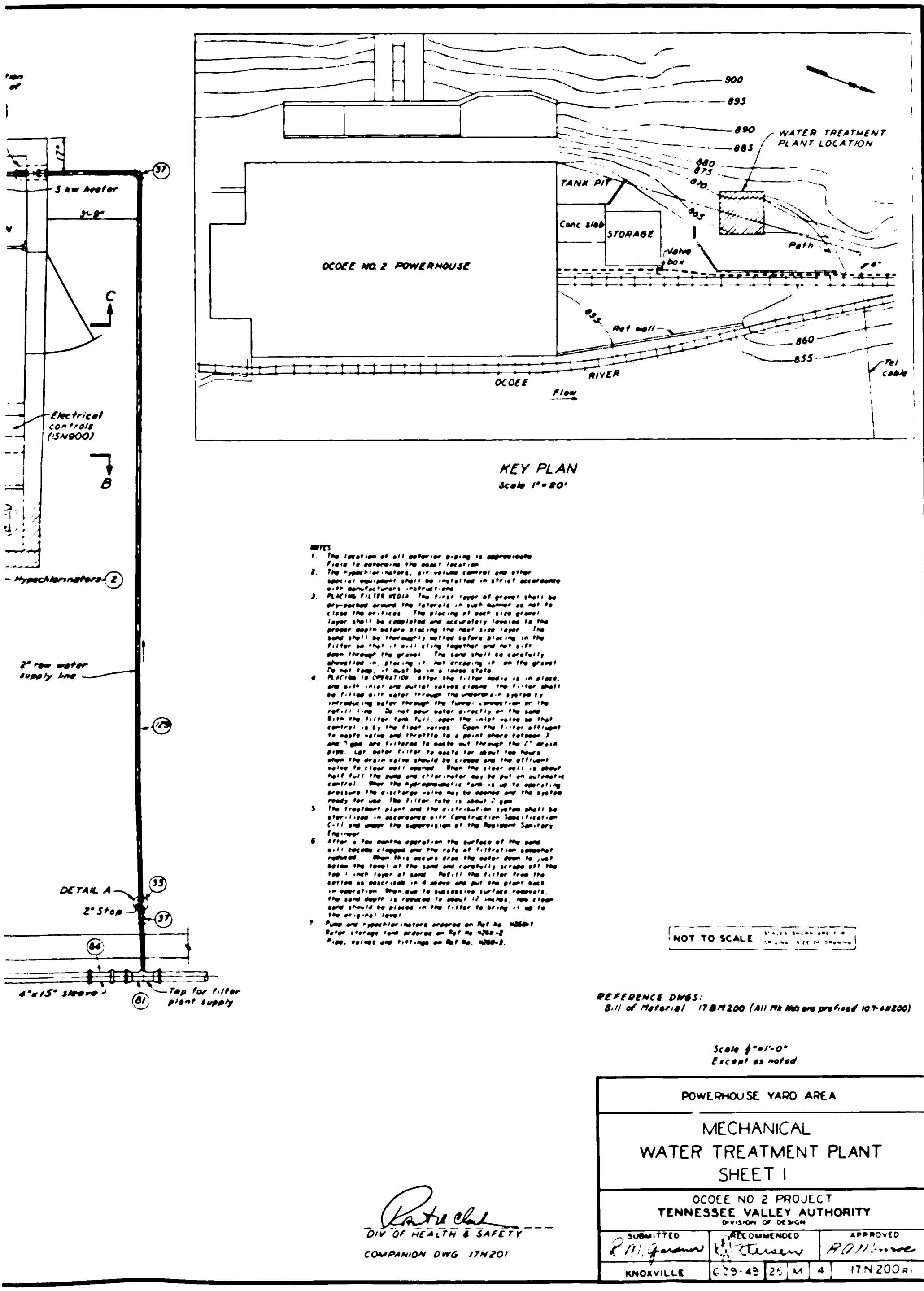
The filter media consists of 12 inches of graded gravel and 3 feet of clean plaster sand. Every 1 or 2 months, or whenever the organic slime growth on the filter surface has built up to such an extent that the filter rate is reduced appreciably, the upper 1 or 2 inches of sand is carefully removed and discarded. After a few years' use, the sand bed is reduced to such an extent that replacement of sand is necessary. No sand washing facilities are provided or justified in this small plant.

The clearwell, from which the service pump takes its suction, has a full capacity of 2,100 gallons. This relatively large capacity was considered necessary to take care of peak loads because the filter has no ability to supply any but the average daily load. The clearwell has an overflow, a valved drain and a float valve on the filter effluent line where it enters the clearwell. When the well is full the float valve closes and the filter automatically ceases to function.

A hydropneumatic tank, having a capacity of 128 gallons between pressure limits of 50 and 30 pounds per square inch is located in the filter plant and supplies pressure water to the hydro plant. A pressure switch on this tank controls the operation of the service pump and hypochlorinator. The tank is equipped with a pressure relief valve, a drain, a manhole, an aspirator for replenishing air, and a water level gage glass.

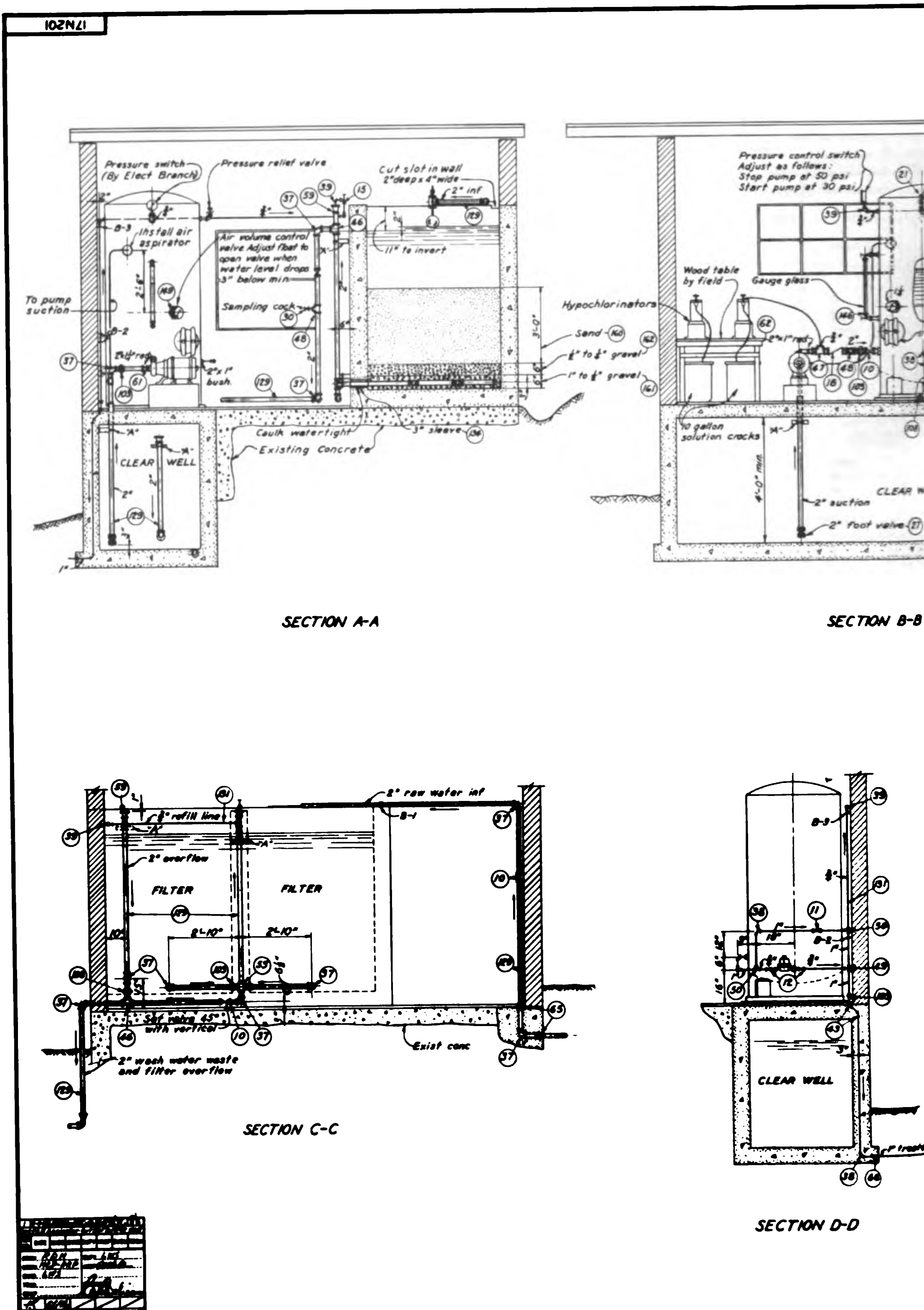
The pump is the close-coupled horizontal centrifugal type, of 35-gallon-per-minute capacity at 150-foot total dynamic head, driven by electric motor.

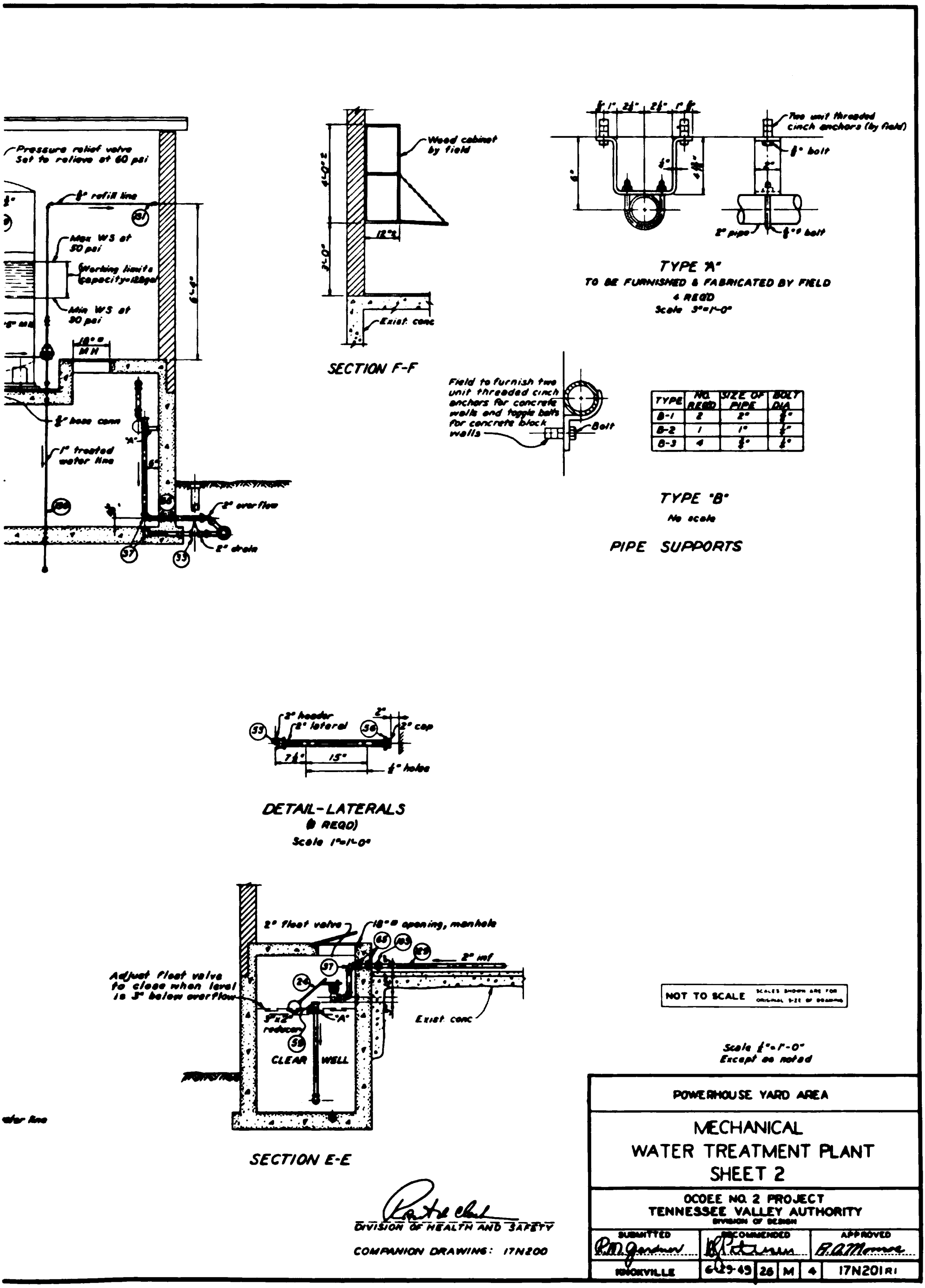

17N200
Place stones below underdrains to hold them level
Cut slot 2" deep
Thermostat
SAND STORAGE BIN
PLAN
SECTION G-G
TO BE FURNISHED AND FABRICATED BY FIELD
DETAIL-MANHOLE FRAME & COVER
Scale 1½"=1'-0"
Bars 1"x½"
Anchor bars
2" effluent
2" soil pipe
OPERATORS CABINET
Booster pump 35 gpm @ 150 TDH
¾" meter
2" drain
DETAIL A 2" stop
MAN-HOLE
Sampling cock
2" overflow
2" "P" trap
2" discharge
Air aspirator
2" suction
Hydropneumatic tank
Tank to be installed before walls are erected
grade
3" pipe
DETAIL A
Scale 1"=1'-0"
2" soil pipe-clear well overflow and drain and filter wash water waste
1" treated water to power plant
Existing retaining wall
Connect 1" pipe to existing 1" pipe at this point
Disconnect and replace with blind flange
Existing 4" raw water supply from Big Creek
Existing 1" service to power house
PLAN-WATER TREATMENT PLANT
Scale ¼"=1'-0"
Extend to embankment



900
895
890
885
880
875
870
865
860
855
WATER TREATMENT PLANT LOCATION
TANK PIT
Conc slab
STORAGE
Valve box
Path
4"
OCOEE NO. 2 POWERHOUSE
Ret wall
OCOEE
RIVER
Flow
Tel cable
KEY PLAN
Scale 1" = 20'
5 kw heater
3'-9"
12"
C
B
Electrical controls (ISN900)
Hypochlorinators
2" raw water supply line
DETAIL A
2" Stop
4" x 15" sleeve
Tap for filter plant supply
NOTES
1. The location of all exterior piping is approximate. Field to determine the exact location.
2. The hypochlorinators, air volume control and other special equipment shall be installed in strict accordance with manufacturers instructions.
3. PLACING FILTER MEDIA. The first layer of gravel shall be dry-packed around the laterals in such manner as not to close the orifices. The placing of each size gravel layer shall be completed and accurately leveled to the proper depth before placing the next size layer. The sand shall be thoroughly wetted before placing in the filter so that it will cling together and not sift down through the gravel. The sand shall be carefully shovelled in, placing it, not dropping it, on the gravel. Do not tamp, it must be in a loose state.
4. PLACING IN OPERATION. After the filter media is in place, and with inlet and outlet valves closed, the filter shall be filled with water through the underdrain system by introducing water through the funnel connection on the refill line. Do not pour water directly on the sand. With the filter tank full, open the inlet valve so that control is by the float valves. Open the filter effluent to waste valve and throttle to a point where between 3 and 5 gpm are filtered to waste out through the 2" drain pipe. Let water filter to waste for about two hours when the drain valve should be closed and the effluent valve to clear well opened. When the clear well is about half full the pump and chlorinator may be put on automatic control. When the hydropneumatic tank is up to operating pressure the discharge valve may be opened and the system ready for use. The filter rate is about 2 gpm.
5. The treatment plant and the distribution system shall be sterilized in accordance with Construction Specification C-11 and under the supervision of the Resident Sanitary Engineer.
6. After a few months operation the surface of the sand will become clogged and the rate of filtration somewhat reduced. When this occurs draw the water down to just below the level of the sand and carefully scrape off the top 1 inch layer of sand. Refill the filter from the bottom as described in 4 above and put the plant back in operation. When, due to successive surface removals, the sand depth is reduced to about 12 inches, new clean sand should be placed in the filter to bring it up to the original level.
7. Pump and hypochlorinators ordered on Ref No. N260-1
Water storage tank ordered on Ref No. N260-2
Pipe, valves and fittings on Ref No. N260-3.
NOT TO SCALE
REFERENCE DWGS:
Bill of Material 17BM200 (All Mk Nos are prefixed 10?-6N200)
Scale 1/2" = 1'-0"
Except as noted
DIV OF HEALTH & SAFETY
COMPANION DWG 17N201
POWERHOUSE YARD AREA
MECHANICAL
WATER TREATMENT PLANT
SHEET 1
OCOEE NO 2 PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-29-49
25
M
4
17N200R1

PLATE 25


Pressure switch (By Elect Branch)
Pressure relief valve
Cut slot in wall 2" deep x 4" wide
2" inf
Install air aspirator
Air volume control valve Adjust float to open valve when water level drops 3" below min
Sampling cock
11" to invert
To pump suction
2"x1" bush.
Sand
1" to 1/4" gravel
Caulk watertight
Existing Concrete
3" sleeve
CLEAR WELL
Pressure control switch Adjust as follows: Stop pump at 50 psi Start pump at 30 psi
Wood table by field
Gauge glass
Hypochlorinators
10 gallon solution crocks
2" suction
2" foot valve
CLEAR WELL
SECTION A-A
SECTION B-B
2" raw water inf
2" refill line
2" overflow
FILTER
FILTER
2'-10"
2'-10"
with vertical
2" wash water waste and filter overflow
Exist conc
SECTION C-C
CLEAR WELL
SECTION D-D


Pressure relief valve
Set to relieve at 60 psi
refill line
Max WS at 50 psi
Working limits capacity
Min WS at 30 psi
MH
hose conn
1" treated water line
2" overflow
2" drain
Wood cabinet by field
12"
Exist. conc
SECTION F-F
Two unit threaded cinch anchors (by field)
bolt
2" pipe
TYPE "A"
TO BE FURNISHED & FABRICATED BY FIELD
4 REQ'D
Scale 3"=1'-0"
Field to furnish two unit threaded cinch anchors for concrete walls and toggle bolts for concrete block walls
Bolt
TYPE | NO. REQD | SIZE OF PIPE | BOLT DIA
B-1 | 2 | 2"
B-2 | 1 | 1"
B-3 | 4
TYPE "B"
No scale
PIPE SUPPORTS
2" header
2" lateral
2" cap
15"
holes
DETAIL-LATERALS
Scale 1"=1'-0"
2" float valve
18" opening, manhole
2" inf
Adjust float valve to close when level is 3" below overflow
reducer
CLEAR WELL
Exist. conc
SECTION E-E
NOT TO SCALE
Scale
Except as noted
POWERHOUSE YARD AREA
MECHANICAL
WATER TREATMENT PLANT
SHEET 2
OCOEE NO. 2 PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-29-49
26
M
4
17N201R1
DIVISION OF HEALTH AND SAFETY
COMPANION DRAWING: 17N200

Of the two hypochlorinators, one is a spare. Two 10-gallon crocks store a hypochlorite solution from which the two units take their suction. One of the hypochlorinators always starts and stops with the service pump and the solution fed into the service pump discharges so that all water entering the hydropneumatic tank is chlorinated. A transfer switch permits rotating the operation of the units to equalize wear and ensure that one, at least, is always in working order.

The powerhouse treated water distribution system supplying sanitary fixtures only is direct-connected to the hydropneumatic tank.

DISTRIBUTION SYSTEMS

Piping

The treated water distribution systems at TVA hydro plants vary greatly in extent and size. In some plants the system is entirely within the powerhouse and is of small-size piping supplying drinking water and toilet fixtures only. At other plants the systems are extensive with the treatment plant at a distance and service provided—not only for sanitary but also for fire-protection and lawn-sprinkling—for the powerhouse and several related buildings and picnic areas.

At a few of the plants the temporary distribution systems laid by the construction forces during and for construction have been partially kept in service because the areas served have been converted to operated areas beyond the scope of the original design. This applies to construction camps and villages which have been kept as resort and picnic areas not contemplated originally. Fontana Village, particularly, was leased as a resort center to Government Services, Inc., after construction work was completed. During construction this completely equipped village had a school, hospital, shopping center, and a population of 2,000 people. Most of the Fontana Village piping was of a temporary nature; none better than galvanized steel pipe and some even black spiral-welded steel pipe. Rather than replace it immediately a calculated risk was taken and it was left in service to be replaced upon failure.

All permanent piping outside powerhouses 3 inches and larger is cement-lined, cast-iron bell and spigot pipe and fittings with lead or sulfur compound joints with AWWA standard valves with operating nut and valve box. Since 1950 TVA has followed the recommendations of the AWWA and APHA in using sterilized paper packing for all bell and spigot joints. Prior to that time all packing was dry braided jute. This was found to provide an excellent breeding ground for several species of bacteria and consequently was eliminated from use. All other piping is galvanized genuine wrought iron with galvanized malleable-iron screwed fittings for less than 3 inches and cast iron flanged fittings for larger pipe. All valves 3 inches and larger are IBBM with smaller valves all bronze. Some small piping to individual plumbing fixtures is copper with soldered joint fittings and valves.

Valves are installed on all main branches from the distribution system as close to the main line as possible. Sectionalizing valves are also installed frequently and at the appropriate places when-

ever loops are used so that portions of the system may be taken out of service for repair and permit the rest of the system to remain in service.

At some of the plants obtaining raw water from springs, the water is relatively hard and has a tendency to deposit calcium carbonate scale in the piping, especially in the hot water systems. In these cases stabilizing chemicals have been introduced either at the treatment plant or in individual lines to inhibit these formations. Sodium hexametaphosphate, sold under the trade name of "Calgon," has proven very satisfactory for this use.

Wherever treated water fire protection is furnished for the powerhouse grounds not less than 6-inch mains are installed. In some of the older projects 4-inch hydrant branches were used but in all of the later projects 6-inch branches are standard. Similarly, within the powerhouses the 1½-inch fire hose cabinets are supplied by not less than 2-inch mains.

Specifications issued to the construction forces for disinfection of water distribution systems and associated equipment are included in appendix D.

Pumping stations

Pumps of some description are found in connection with all treated water systems except where water is purchased. In the latter cases the water is always at adequate pressure for TVA use. The type of pump varies from small vertical plunger pumps in wells, through horizontal centrifugal pumps as high service pumps in treated plants, to similar pumps in booster stations where variations in reservation topography makes two or more distribution pressure systems necessary.

Vertical plunger-type well pumps are used at Nottely and Watauga for two reasons. These pumps will produce almost constant flow rates under the varying, existing head conditions. This permits the use of constant capacity electric-motor-driven hypochlorinators which operate in parallel with them. These supplies also require pumps of small capacity at high head and these conditions are nicely filled by the characteristics of this type of pump. At other projects, when well or vertical pumps are required, the vertical turbine type is used. In all cases either the head conditions are relatively constant so that a positive displacement hypochlorinator can be used in parallel with no serious variation in dosage rate, or chlorination follows some intermediate treatment.

At all water-treatment plants pumps are necessary to deliver water under pressure to the distribution system and elevated storage tanks for final consumption. In almost all cases the pumps are electric-motor-driven horizontal centrifugal pumps of either the horizontally split case or close-coupled type. Capacities of these pumps vary widely between projects, depending on demand and use. Where fire protection is furnished by treated water the pumps have a capacity at least equal to a standard fire stream if treatment plant clearwell capacity will permit. With no fire-protection service and adequate elevated storage the service pump capacity is usually no more than the design rate of the treatment plant. In all, except very minor plants, there are duplicate pumps with one acting as

a spare unit. A transfer switch is provided so that the pumps may be alternated periodically to equalize wear and to ensure that at least one pump is ready for service at all times. In some cases the second pump is separately controlled so that in emergencies, if the first pump cannot handle the load, it will cut in to increase the flow. At a few plants gasoline-engine-driven emergency pumps are available in case of electric power failure. This was done only at some of the early isolated plants before TVA's integrated power system ensured reliable service to all sections of the valley.

The discharges of all pumps are provided with a check and a gate valve. The check valve prevents backflow through the pump when shut down and the gate valve permits the pump or check valve to be taken out of service for repair or inspection. The suctions of all horizontal pumps are equipped with gate valves if the suction is flooded or with foot valves if the units start under a negative head. The latter type of installation is only used at attended stations and a source of priming water is provided in case of foot valve leakage.

The control of all pumps is by either pressure or float switches. Most raw water supply pumps to treatment plants are controlled by float switches operating in the treatment plant's clearwell. High service pumps are controlled by either pressure switches in the distribution system or on hydropneumatic storage tanks, or by float switches in elevated storage tanks. One exception is a low water control switch in the water supply well at Chatuge. In anticipation of overpumpage during low ground water periods an electrode-type switch was fastened to the lower end of the deep well pump and both installed together. This switch will stop the pump at low water and thus prevent damage which would result if operated dry.

Storage

Some type of elevated or pressure storage of water is necessary at all projects to take care of all peak loads and demands in excess of service pump capacity and to provide some emergency supply in case of pump failure. At projects such as Douglas, Cherokee, and Wilson, where treated water is used for fire protection, elevated steel storage tanks of 50,000 gallons or more capacity are provided. Figure 225 (top) shows a typical elevated steel storage tank at Hiwassee treatment plant and wooden tanks at ground level. At Fontana, Watts Bar, and Hales Bar, a natural elevation is conveniently located and a steel or wood stave tank is placed on the high ground and the cost of the steel supporting structure is eliminated. Figure 226 shows a view of the Fontana water-treatment plant and the use of wooden storage tanks.

At projects where treated water is provided for sanitary purposes only, storage is required in much less quantity. Where possible a natural elevation is utilized for a simple tank. Examples of this are at Watauga where a steel tank with pump controls in an adjacent manhole are buried on a hillside above the dam, and at Apalachia where a gravity tank and pump controls are located in the butterfly valve chamber on the penstock. Where no convenient high point is available hydropneumatic tanks are installed. Figure 235 shows an interior view of the Ocoee No. 3 pressure filter plant and

its hydropneumatic water storage tank. These are the least desirable because so little volume is available for useful storage; about half the tank capacity must be reserved for air to provide a not too widely fluctuating pressure, and about one quarter of the remaining water is at too low a pressure for normal use. Another inconvenience is that compressed air is usually required to build up the required air pressure in the tank and replenish it occasionally to compensate for that absorbed by the water. Advantages for the hydropneumatic tank is that it can be located anywhere convenient within the powerhouse; there is no freezing problem; it provides an excellent place to locate pressure switches; and serves as a surge tank to cut down water hammer.

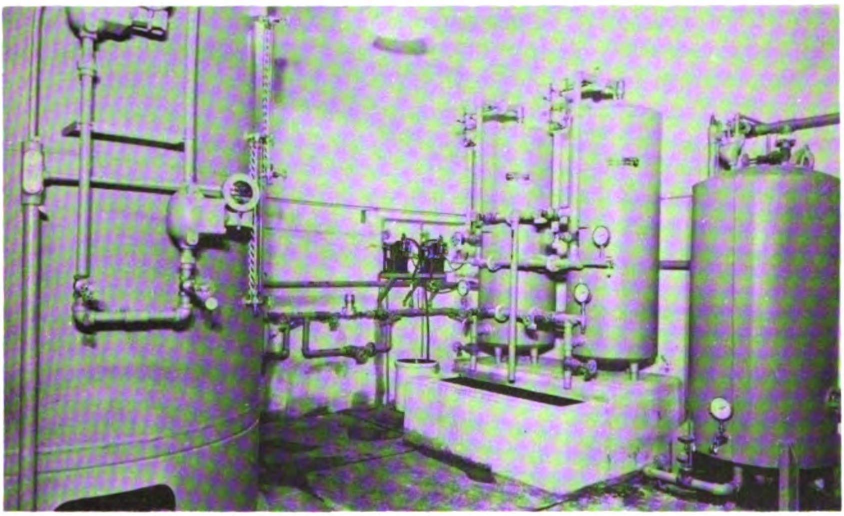


FIGURE 235.—*Pressure filter plant—hydropneumatic storage tank at left—Ocoee No. 3.*

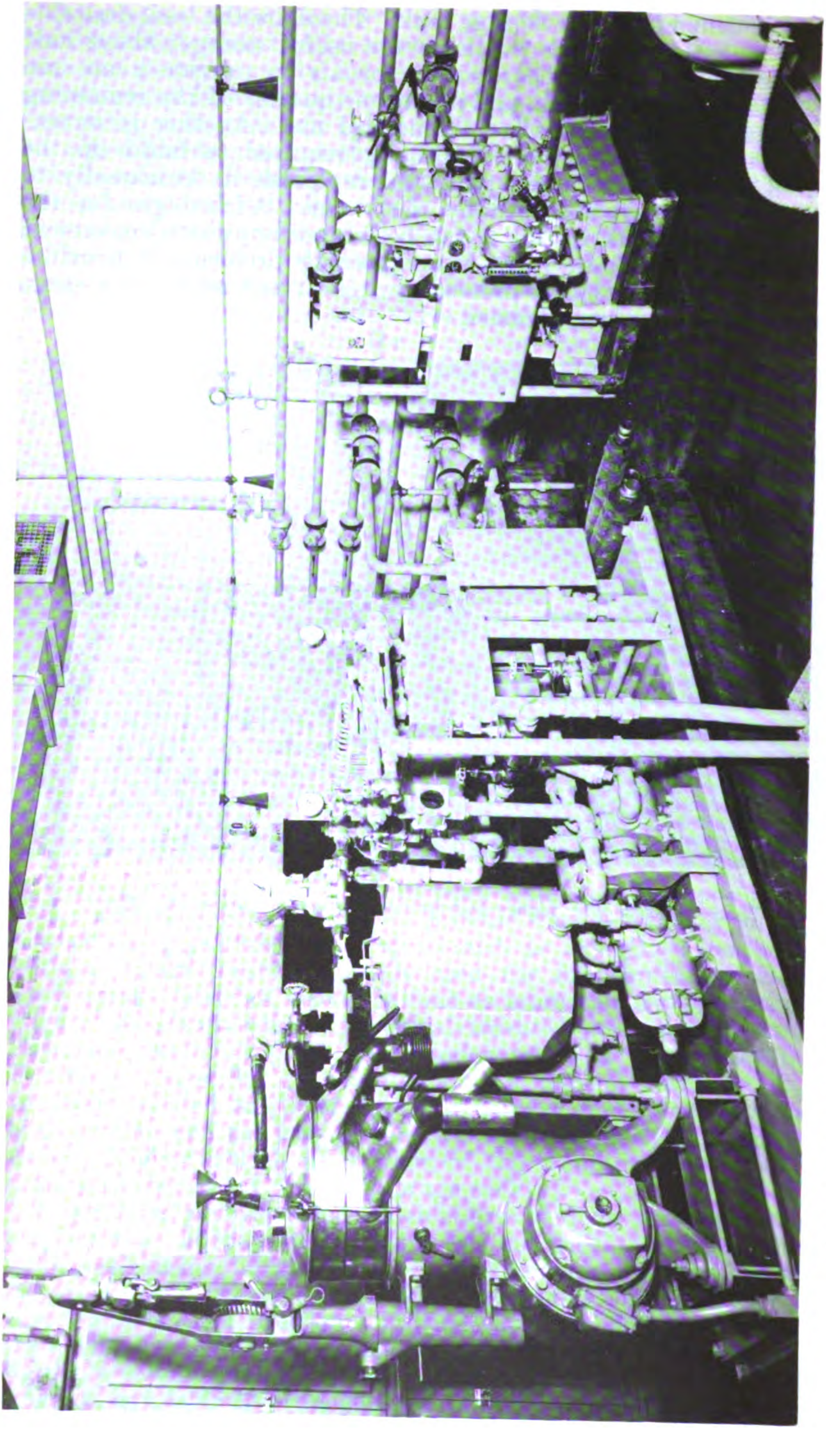


FIGURE 236.—*Oil purification equipment for insulating oil, at left, and for lubricating oil, at right—Ocoee No. 3.*

CHAPTER 10

OIL SYSTEMS AND HANDLING

Oil obtained for use in TVA hydroelectric power stations is divided into three general classifications according to the use for which it is intended. These oil classifications and the systems in which each oil is used are: (1) medium lubricating oil in generator, governor, and turbine oil systems, in sluice and head gate oil systems, and in the generator rotor jacking systems—the foregoing systems are water free; (2) heavy lubricating oil—subject to mixing with water—in the turbine runner hub oil systems; and (3) insulating oil in insulating oil systems for electrical equipment. Separate specifications are prepared for each oil classification subject to the approval of the manufacturers of the various equipment in which the oil is to be used.

Each of the several systems, together with the characteristics of the oil the system requires, is discussed in this chapter.

System features

Separate purification.—To avoid the mixing of these three types of oil, separate purification equipment (fig. 236), transfer pumps, storage tanks, and piping systems are usually provided for each type. This equipment is arranged to perform the various operations required to transfer, store, or purify the oil. Table 10 presents pertinent data covering the lubricating oil systems and table 11 the insulating oil systems in each of the 23 hydro plants, described in detail in chapter 2.

Generator, governor, and turbine.—A typical list of operations performed by the generator, governor, and turbine oil system in which the same medium lubricating oil is used is as follows:

1. Filling either tank from outside fill box, using clean-oil pump.
2. Filling clean-oil tank from outside fill box through purifier.
3. Purifying oil from dirty-oil tank and transferring to clean-oil tank, using purifier pumps.
4. Flushing headers with clean oil, using clean-oil pump.
5. Filling governor sump tank, using clean-oil pump.
6. Filling generator bearing, using clean-oil pump.
7. Filling turbine bearing sump tank, using clean-oil pump.
8. Draining governor sump and pressure tank, using dirty-oil pump.
9. Draining generator bearing, using dirty-oil pump.
10. Draining turbine bearing sump tank, using circulating pump in turbine pit.
11. Removing oil from system.

TABLE 10.—*Lubricating oil system data*

Project	Clean-oil pump capacity, gallons per minute	Dirty-oil pump capacity, gallons per minute	Purifier capacity, gallons per hour	Storage capacity, gallons: Clean-oil tank	Storage capacity, gallons: Dirty-oil tank	Equipment oil capacity, gallons per unit: Units	Governor system	Turbine guide bearing	Generator thrust and guide bearing
Norris	[a] 30		[b] 1,200	2,400	2,400	1, 2	1,200 to 1,500	75	750
Wheeler	50		[b] 1,200	5,000	5,000	1 to 8	1,200	Water-lubricated	[d] 50+1,375
Pickwick	50		285	8,000	8,000	1 to 6	3,350	do	3,300
Guntersville	30	30	300	3,000	3,000	1, 2, 3	1,600	do	1,400
						4	1,600	do	2,000
Chickamauga	30	30	300	3,500	3,500	1, 4	2,000	do	2,150
						2, 3	1,900	do	2,150
Hiwassee	[a] 30		300	4,700	4,700	1	900	60	800
						2	800	160	3,350
Watts Bar	30	30	375	3,800	3,800	1, 2, 4, 5	1,954	Water-lubricated	1,550
						3	2,592	do	1,550
Wilson Units 1 to 8	3 at 35		([e])	4,440	2,400	1 to 8	Water-operated	do	250
Wilson Units 9 to 18	30	30	375	3,000	3,000	9 to 18	1,575	do	900
Cherokee	30	30	350	3,660	3,660	1, 2	2,050	80	1,200
						3, 4	2,350	80	1,200
Douglas	30	30	350	3,660	3,660	1, 2	2,050	80	1,200
						3	2,350	80	1,200
						4	2,350	80	1,300
Ocoee No. 3	30	30	350	2,500	2,500	1	1,420	60	760
Apalachia	30	30	350	3,000	3,000	1, 2	1,420	45	760
Fort Loudoun	30	30	350	4,500	4,500	1 to 4	1,700	Water-lubricated	2,650
Kentucky	30	30	350	5,100	5,100	1	3,500	do	[d] 80+1,450
						2, 3, 4, 5	3,000	do	[d] 80+1,450
Fontana	30	30	350	3,500	3,500	1, 2, 3	1,500	100	1,550
Watauga	37	37	350	3,210	3,210	1, 2	480	55	570
Wilbur	[a] 20		([f])	[e] 785		4	325	Water-lubricated	340
South Holston	24	24	350	2,110	2,110	1	590	23	1,050
Hales Bar	38.5	38	350	3,300	3,300	15, 16	1,150	Water-lubricated	2,000
Boone	33.5	33.5	375	2,125	2,125	1, 2, 3	645	120	1,100
Fort Patrick Henry	36	36	350	2,150	2,150	1, 2	750	50	1,100
Chatuge	[a] 26		([g])	[e] 1,150		1	400	Grease-lubricated	625
Nottely	[a] 28		([g])	[e] 1,150		1	400	do	650

[a] Clean- and dirty-oil transfer pump.
[b] Purifier used for both lubricating and insulating oil.
[c] One portable storage tank for transporting clean and dirty oil to and from purification facilities.
[d] Upper guide and lower thrust and guide bearing reservoirs, respectively.
[e] Continuous oil filters are utilized.
[f] Oil is purified at Watauga.
[g] Oil is purified at Hiwassee.

TABLE 11.—*Insulating oil system data*

Project	Clean-oil pump capacity, gallons per minute	Dirty-oil pump capacity, gallons per minute	Purifier capacity, gallons per hour		Storage tank capacity, gallons		
			Without pressure	With pressure	Clean oil	Dirty oil	
						Transformer	Circuit breaker
Norris	[a] 200	----	1,200	[b] 1,200	11,900	11,900	7,950
Wheeler	[a] 100	----	1,200	[b] 1,200	12,000	12,000	7,500
Pickwick	[i] 100 and 25	----	1,200	1,200	24,000	8,000	16,000
Guntersville	100	100	600	900	6,450	12,900	6,450
Chickamauga	100	None	600	900	[f] 8,500+5,600	8,500	5,600
Hiwassee	100	None	600	900	9,000	9,000	9,000
Watts Bar	100	100	600	900	7,000	14,000	7,000
Wilson	(d)	(d)	[c] 150 to 1,000	----	30,000	20,000	8,000
Power Service Building	[a] 100	----	1,200	1,200	1,035	1,035	----
Power Service Building (yard)	115	115			[g] 48,000	[h] 48,000	----
Cherokee	100	None	600	900	6,420	10,060	6,420
Douglas	100	None	600	900	6,420	10,060	6,420
Ocoee No. 3	100	100	600	900	7,000	7,000	7,000
Apalachia (powerhouse)	100	None	600	[e] 900	6,025	12,050	None
Apalachia (switchyard)	[a] 100	----			6,500	None	6,500
Fort Loudoun	100	100	600	900	6,400	9,000	6,400
Kentucky	100	None	600	900	6,450	12,900	6,450
Fontana	100	100	600	900	6,820	10,380	6,820
Watauga (powerhouse)	120	120	600	[e] 900	7,350	7,350	None
Watauga (switchyard)	115	115			10,620	None	7,050
South Holston	120	120	600	900	7,040	7,040	7,040
Hales Bar	120	122	600	900	13,700	13,700	7,050
Boone	100	100	600	600	11,600	11,600	7,050
Fort Patrick Henry	56	56	600	900	5,165	5,165	1,850
Chatuge	[a] 55	----	(j)	(j)	[k] 3,200	----	----
Nottely	[a] 59	----	(j)	(j)	[k] 4,280	----	----

[a] Clean- and dirty-oil transfer pump.
[b] Purifier used for both insulating and lubricating oil.
[c] 150-g.p.m. capacity for operation of two purifiers in series with bad oil and 1,000-g.p.m. capacity for operation in parallel with fair oil. Acid-correction equipment also provided.
[d] Transfer pumps consist of three ¼ horsepower, four ¾ horsepower, and two 5 horsepower.
[e] Portable purifier.
[f] Clean transformer oil tank and clean circuit breaker oil tank capacities, respectively.
[g] Including one 12,000-gallon tank for either clean or acid-corrected oil.
[h] Including one 12,000-gallon tank for either dirty or acid oil.
[i] Insulating and OCB oil transfer pumps, respectively.
[j] Portable purifier to be supplied by DPO.
[k] Oil storage tank utilized for clean or dirty oil.

Insulating oil equipment.—Similarly the insulating oil equipment is arranged to perform a typical list of operations as follows:

1. Filling either dirty-oil tank from outside fill box, using dirty-oil pump.
2. Purifying oil from either dirty tank and transferring to clean tank, using purifier pumps.
3. Flushing headers with clean oil, using clean-oil pump.
4. Filling electrical equipment from clean tank, using clean-oil pump.
5. Draining electrical equipment into the appropriate dirty tank, using dirty-oil pump.
6. Purifying oil in electrical equipment by circulating through purifier.
7. Using portable purifying equipment for yard service.
8. Circulating oil in any tank through purifier.
9. Removing oil from system, using appropriate pump.

Turbine runner hub.—Runner hub oil systems, using a heavy lubricating oil, are provided for all units with adjustable-blade, propeller-type runners, except the two units at the Fort Patrick Henry project which have grease-lubricated runner hubs. The runner hub oil systems usually consist of a permanent pipe header and hose connections with provision for connecting the hub through a portable pump to portable storage tanks for filling and emptying. During inspection or dismantling of a unit, it is necessary to remove this oil from the hub. Since this is a rare procedure, only one portable pump and two 970-gallon portable storage tanks were purchased to be moved from plant to plant as required.

Sluice gate.—Hydraulically operated sluice gates, using oil as the operating medium, are installed at Fontana, Cherokee, Douglas, Watauga, South Holston, and Boone projects. The oil system for sluice gates uses a medium lubricating oil and has provision for filling the system through a strainer from portable drums. The equipment consists of a storage tank for working capacity (approximately 330), an oil pump (with an additional standby unit where several gates are involved) rated at 20 gallons per minute and 1,200 pounds per square inch, and the piping system required for regulation of the sluice gates.

Head gate.—An oil system for head gates, similar in operation to the oil system for sluice gates described above, is provided at Chatuge and Nottely projects. In addition to the normal raising and lowering of the gates using the 20-gallon-per-minute pump, these systems have provision for rapid emergency lowering of the gates by operation of a second larger capacity oil pump. At Chatuge a 120-gallon-per-minute, 800-pound-per-square-inch, emergency oil pump is provided with push-button control stations on the governor cabinet, at the pump, and in Hiwassee control room (from which the Chatuge generating unit is remotely controlled) to start the pump and lower the head gates. The gates are held in the normally open position by safety studs. Initial pressure in the gate cylinders breaks the safety studs, which later have to be replaced. Limit switches are set to stop the pump after both gates are closed. This pump may also be started automatically by a float switch indicating excessive leakage of water in the power conduit. At Nottely a 120-gallon-per-minute, 1,000-pound-per-square-inch, emergency oil pump is provided with the same control features as at Chatuge except that no float switch is provided or necessary.

Generator rotor jacking.—The generator rotor jacks, using a medium lubricating oil, are furnished by the generator manufacturer for lifting the rotating portion of vertical generating units. Oil pressure is applied by means of a portable high-pressure hand pump to the air brake cylinders and additional jacks if required. A high-pressure piping system supplies and returns oil, with a drain line to a receptacle for leakage oil.

Drawings and instructions

A single-line drawing or valve operation diagram is made for each of the oil systems with numbered valves and equipment descriptions. This drawing serves as a guide to the field forces during erection of the system and enables the operator to perform the various functions of the system according to written instructions during operation. Typical operating instructions such as included in appendix E are prepared and issued to the Division of Power Operations for the lubricating, insulating, and sluice gate oil systems.

GENERATOR, GOVERNOR, AND TURBINE OIL SYSTEMS

A typical diagram of a governor and lubricating oil system is shown in plate 27, and a typical list of operations performed by such a system appears in the preceding pages of this chapter. The specifications of lubricating oil for use under the above heading are somewhat variable, with the final limiting factor being the approval of the equipment manufacturers. A medium lubricating oil for use in a water-free system is purchased, the characteristics of which most nearly meet the requirements of the various services for which it is intended. For simplicity of the lubricating oil system, one oil with suitable characteristics for use in the generator and turbine bearings and in the governor oil system is obtained. Table 10 presents pertinent data concerning the lubricating oil systems and equipment as installed in TVA projects.

Oil characteristics

Detailed requirements of this type of oil (medium lubricating) are within the following ranges:

Color NPA—2 maximum
Carbon residue by weight, percent—0.03 maximum
Flash point, degrees Fahrenheit—from 410° to 350° F. minimum
API gravity—from 28 to 20 minimum
Pour point, degrees Fahrenheit—from −10° to +15° F.
Viscosity, SSU
- At 100° F.—from 240 to 320
- At 130° F.—from 115 to 150
- At 210° F.—from 45 to 50

Neutralization number—from 0.02 to 0.07 maximum
Saponification number—from 0.08 to 0.50 maximum
Steam emulsion number—from 55 to 75 seconds maximum
Corrosion of copper strip at 212° F.—pass
Demulsibility—1620
Viscosity index—from 90 to 60 minimum

Some properties of this lubricating oil, such as the saponification, steam emulsion, and demulsibility, are not too significant since there is little chance for the oil to become contaminated with water.

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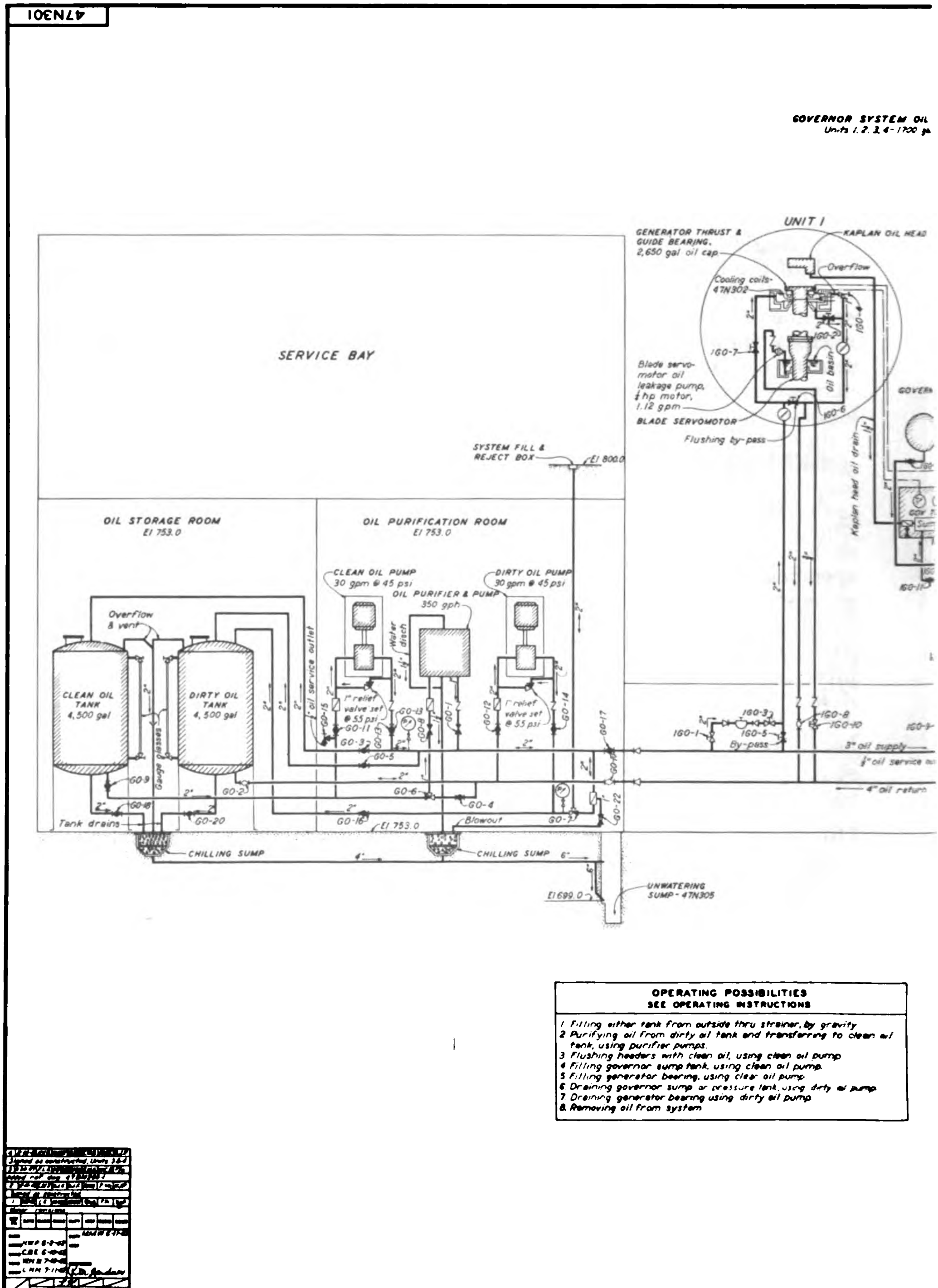

47N301
GOVERNOR SYSTEM OIL
UNIT 1
GENERATOR THRUST & GUIDE BEARING, 2,650 gal oil cap.
KAPLAN OIL HEAD
Overflow
Cooling coils-47N302
Blade servo-motor oil leakage pump, ¼ hp motor, 1.12 gpm
BLADE SERVOMOTOR
Flushing by-pass
Oil basin
Kaplan head oil drain
SERVICE BAY
SYSTEM FILL & REJECT BOX
El 800.0
OIL STORAGE ROOM
El 753.0
OIL PURIFICATION ROOM
El 753.0
CLEAN OIL PUMP 30 gpm @ 45 psi
DIRTY OIL PUMP 30 gpm @ 45 psi
OIL PURIFIER & PUMP 350 gph
Overflow & vent
CLEAN OIL TANK 4,500 gal
DIRTY OIL TANK 4,500 gal
Gauge glasses
Water disch
1" relief valve set @ 55 psi
oil service outlet
Tank drains
CHILLING SUMP
Blowout
El 753.0
UNWATERING SUMP-47N305
El 699.0
3" oil supply
4" oil return
By-pass
OPERATING POSSIBILITIES
SEE OPERATING INSTRUCTIONS
1 Filling either tank from outside thru strainer, by gravity
2 Purifying oil from dirty oil tank and transferring to clean oil tank, using purifier pumps.
3 Flushing headers with clean oil, using clean oil pump
4 Filling governor sump tank, using clean oil pump.
5 Filling generator bearing, using clean oil pump.
6 Draining governor sump or pressure tank, using dirty oil pump
7 Draining generator bearing using dirty oil pump
8 Removing oil from system

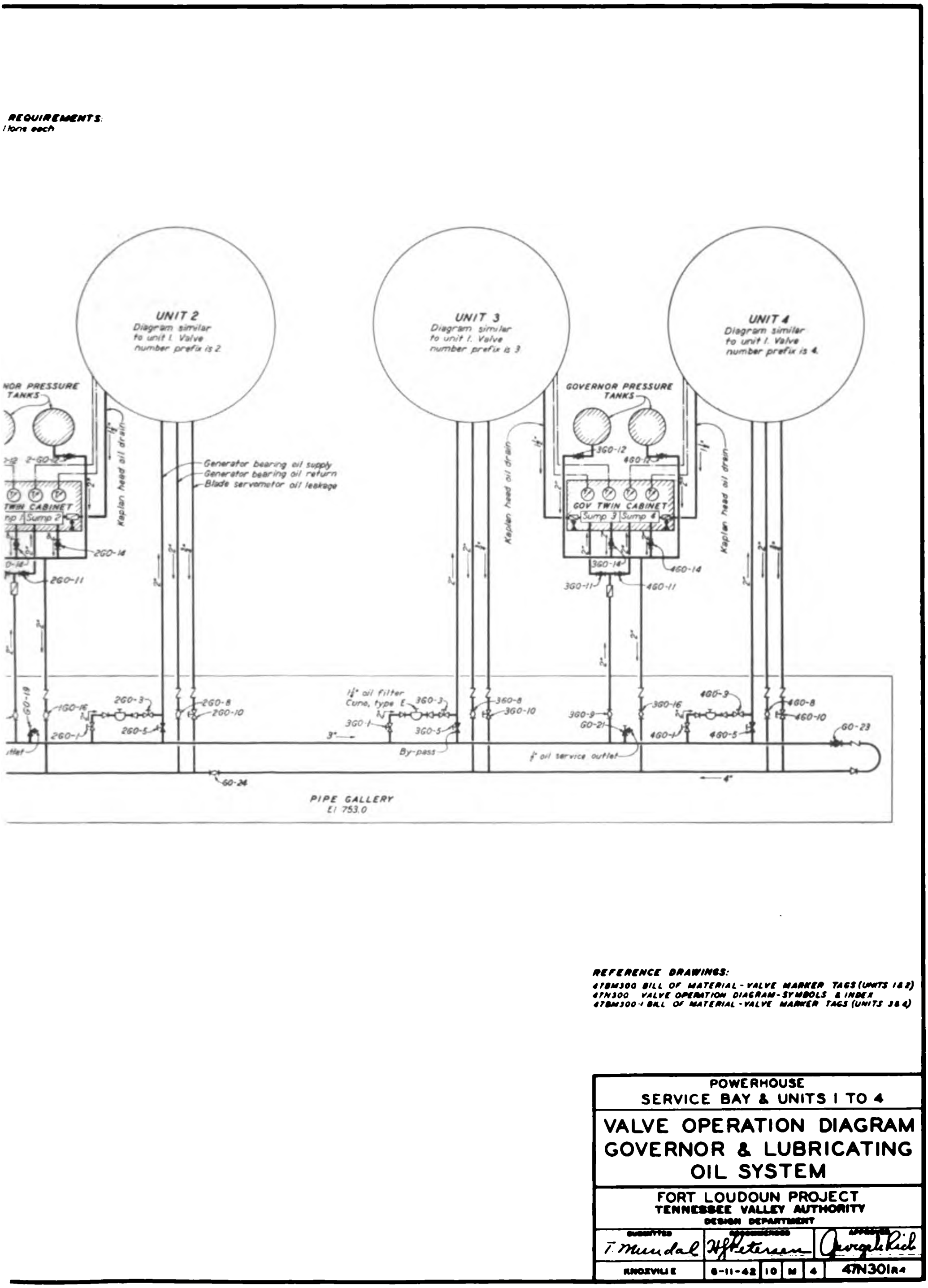

REQUIREMENTS:
1 tons each
UNIT 2
Diagram similar to unit 1. Valve number prefix is 2
UNIT 3
Diagram similar to unit 1. Valve number prefix is 3
UNIT 4
Diagram similar to unit 1. Valve number prefix is 4
GOVERNOR PRESSURE TANKS
Generator bearing oil supply
Generator bearing oil return
Blade servomotor oil leakage
Kaplan head oil drain
GOV TWIN CABINET
Sump 3
Sump 4
PIPE GALLERY
El 753.0
By-pass
oil service outlet
REFERENCE DRAWINGS:
47BM300 BILL OF MATERIAL - VALVE MARKER TAGS (UNITS 1 & 2)
47N300 VALVE OPERATION DIAGRAM - SYMBOLS & INDEX
47BM300-1 BILL OF MATERIAL - VALVE MARKER TAGS (UNITS 3 & 4)
POWERHOUSE
SERVICE BAY & UNITS 1 TO 4
VALVE OPERATION DIAGRAM
GOVERNOR & LUBRICATING OIL SYSTEM
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
6-11-42
47N301R4

PLATE 27

It is the policy of TVA to purchase replacement or "makeup" oil for any specific plant by brand name to be identical with the original oil furnished. This policy would apply even though the different brands of oil, when tested, showed the same characteristics, to avoid the possibility of noncompatibility of additives.

Generator bearings

A combination thrust and guide bearing located below the rotor is specified, but an additional guide bearing above the rotor is permitted if recommended by the manufacturer. An upper guide bearing above the rotor was furnished on the Wheeler and Kentucky units. This is often recommended when a spring thrust bearing is used and when the lower guide bearing is at a considerable distance below the center of the rotor. These are shoe-type, self-cooled, oil-immersed bearings.

A single guide bearing located below the rotor, in the same oil reservoir as the thrust bearing, is considered adequate when located at an elevation near the center of mass of the rotor and when a solid-type thrust bearing is used. The guide bearing used on most generators is of the multiple-shoe, babbitted type, capable of adjustment as to diameter and center.

Kingsbury type, flat thrust bearings were used on most TVA generators up to 1949. The Kingsbury type has a smooth rotating runner plate and several stationary babbitted shoes, each of which is supported at about its center by a spherical-ended, hardened jackscrew. This arrangement provides solid support for the shoes, adjustment for plumbing the shaft, and adjustment for loading the shoes equally. The General Electric spring-type thrust bearing also has a smooth rotating runner plate, but instead of separate babbitted shoes, it has a thin, flexible, stationary, babbitted plate supported on a large number of springs. By 1949 the spring bearing had been improved by using separate babbitted shoes or stationary segments, and this type has been used on several later installations.

The thrust and guide bearings are located below the rotor in a common oil reservoir cooled by water coils. With this arrangement the lubricating oil and its cooling water are below the rotor where leakage is not likely to be thrown into the windings.

Turbine bearings

As discussed in chapter 3, "Hydraulic Turbines," all units in the storage or tributary hydro plants have oil- or grease-lubricated babbitt-lined bearings with the exception of Wilbur unit 4 which has a water-lubricated bearing. All units in the main-river plants installed to date have water-lubricated main turbine bearings. This type of bearing, however, is no longer specified for new plants due to the abrasives in the bearing lubricating water with the attendant high maintenance cost. Recently designed Chatuge and Nottely hydro units are equipped with grease-lubricated turbine guide bearings.

Where oil-lubricated guide bearings are furnished, the bearing is located above the stuffing box and arranged to permit at least ¾-inch vertical movement of the rotating parts. Lubricating oil is circulated through the bearing, being pumped from the oil reser-

voir below the bearing through a filter, flow indicator, and oil cooler, if required, to the oil reservoir above the bearing. The oil then flows by gravity through the bearing oil grooves to the lower reservoir. An overflow pipe carries excess oil from the upper to the lower reservoir.

Two float switches in the upper oil reservoir control the operation of two electric-motor-driven positive displacement oil pumps; one pump operates on the alternating-current circuit and the other on the direct-current station battery service, thus assuring a constant supply of lubricating oil.

A thermal relay, temperature detectors, and remote indicating mercury-type thermometers are furnished for emergency shutdown, annunciation, and temperature indication or recording to protect the bearing and provide safe and automatic operation of the system.

Governor

Governing systems as specified by TVA are the relay valve "actuator" type with motor-driven governor head, complete with auxiliary control mechanism, restoring mechanism, oil pressure system, instruments, gages, and accessory equipment. All later-designed units are of the automatic type and equipped for operation by remote control, and progress is now being made to convert as many as possible of the older units to automatic remote control. The governor automatic equipment includes necessary starting solenoids, timing devices, automatic generator brake control equipment, automatic shutdown devices, and automatic wicket gate lock.

The governing system is designed for operation with oil pressure varying from a maximum of 300 pounds per square inch to a minimum of 250 pounds per square inch. With oil pressure of 250 pounds per square inch, the system is capable of operating the gate servomotors of the turbine through a full stroke, either opening or closing, in not more than 4 seconds.

The oil supply system includes two motor-driven pumps, one pressure tank, sump tank, accessory parts, and all necessary piping. Chapter 4, "Governors for Hydraulic Turbines," gives a more complete description.

For all units with adjustable-pitch propeller-type runner blades, oil for the Kaplan control is supplied by the governor system to the oil distributor head. A Kaplan oil head drain to the governor sump and an oil return to the dirty lubricating oil tank from the sump pump at the blade servomotor oil basin are usually provided.

Purification equipment

A centrifugal oil purifier is provided at most power stations for purification of lubricating oil. Exceptions are several small stations at which portable storage tanks remove the lubricating oil to some other nearby plant for purification and return of the oil. The lubricating oil purifiers are usually of 350-gallon-per-hour capacity, with several having been installed with 300- or 375-gallon-per-hour capacity. These units are self-contained and consist of a centrifuge, centrifuge motor, motor-driven pump or pumps, electric heaters, automatic temperature control, thermometers, strainers, meters, gages, valves, piping, electrical equipment, and other accessories

necessary for satisfactory operation. Figure 237 shows a typical lubricating oil purifier installation. Typical oil purifier specifications are included in appendix B.

The mixture of dirty oil and water is subjected to high centrifugal force, thus causing the water, dirt, and sludge to separate from the oil. By proper selection of the discharge ring or ring dam of the centrifuge, a high percentage of the impurities in the oil is removed, and clean oil is returned to the system.

The centrifuge of the lubricating oil purifier is specified to be capable of purifying dirty lubricating oil at a rate of not less than 350 gallons per hour, at a temperature of not over 140° F. The capacity is determined by test runs at the manufacturer's plant in accordance with paragraphs E–1, E–1a, E–1c and E–2 of the Bureau of Engineering, U.S. Navy Department Specification 66P2–(INT), using Navy 2190 oil at a purifying temperature of 130° F. Such tests are usually witnessed by TVA inspectors and copies of test reports are submitted to the Mechanical Design Branch for approval.

Pumps

A few of the first TVA hydroelectric power stations were equipped with only one lubricating oil transfer pump to handle both clean and dirty oil. Experience indicated, however, that the added initial cost to provide a separate pump for the clean and the dirty oil was offset by a saving in operating time and the advantage of eliminating the possibility of mixing dirty oil with clean oil. All later projects, which are equipped with a purifier, have two electric-motor-driven, positive-displacement pumps—one for clean oil and one for dirty oil. Figure 237 shows a typical 2-pump arrangement. Where the oil is to be taken to another station for purification, one transfer pump is furnished to both fill and drain the equipment.

Normally, the 30-gallon-per-minute clean-oil pump is used to fill the system, flush the headers, fill the governor sump tank, generator

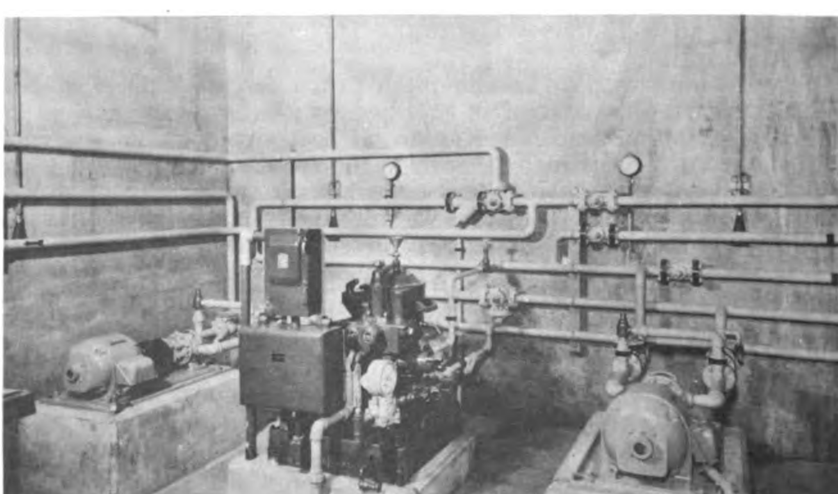


FIGURE 237.—*Lubricating oil purifier and pumps—Fort Loudoun.*

bearing, and turbine bearing sump tank, and remove clean oil from the system. The 30-gallon-per-minute dirty-oil pump is normally used to drain the governor sump and pressure tank and the generator bearing, and remove dirty oil from the system. The circulating oil pump in the turbine pit, which is furnished by the turbine manufacturer, is used to drain the turbine bearing sump tank.

Lubricating oil transfer pumps purchased by TVA are specified to be horizontal shaft, electric-motor-driven through a flexible coupling. The design capacities of the pumps for the plants are given in table 10. They are positive-displacement pumps, generally the herringbone-gear type or swing vane principle. Each pump is equipped with a pressure relief or unloading device to protect the pump against excessive pressure in case of throttling in the discharge line. The specified design pressure includes suction lift and friction and the pump must be capable of self-priming for a suction lift of 20 feet. Pump gears or rotors are of heat-treated steel or special alloy iron. Each pump is equipped with a stuffing box and packing or mechanical seals. Motors, 220/440 volts, 3 phase, 60 cycles, are squirrel cage, NEMA Design C, splashproof, high starting torque, for full-voltage start. Motor speeds are limited to 1,200 revolutions per minute for gear-type pumps and 1,800 revolutions per minute for vane- or screw-type pumps.

Typical oil pump specifications are given in appendix B.

Storage tanks

One dirty-oil tank and one clean-oil tank are usually provided, except where the plant is equipped with a portable tank for purification elsewhere. Each tank has sufficient capacity to hold all the governor and lubricating oil of one unit plus approximately 10 percent reserve.

The tanks are cylindrical, welded-steel construction, mounted either horizontally on concrete saddles or vertically on a steel tank base. The tanks have manholes for inspection purposes and either gage glasses or remote indicators to show liquid level. An overflow and vent line from the top of the tank and total drain connection from the bottom are also provided. The tanks are usually in the powerhouse basement, either in or adjacent to the service bay as shown in figure 238.

The inside of the oil storage tanks is sandblasted and factory-painted with one coat of General Electric Co. No. 1248 Glyptal primer and one coat of No. 1201 Glyptal lacquer.

Piping

A complete permanent piping system is provided for transferring lubricating oil from storage to unit, for circulating through purifier (where a purifier is furnished), or for draining the unit to storage. The piping is steel and welded wherever feasible to eliminate leakage and reduce friction losses. All pipe is black steel ASTM A 120, and fittings are either butt-welding or socket-welding type. On pipe sizes above 2-inch, welding rings are utilized at all joints. Lubricated type plug valves are used throughout the system.

Flexibility for the various operations required and prevention of mixing clean and dirty oil are obtained by use of three-way plug valves and check valves in the system. All pump suction lines are

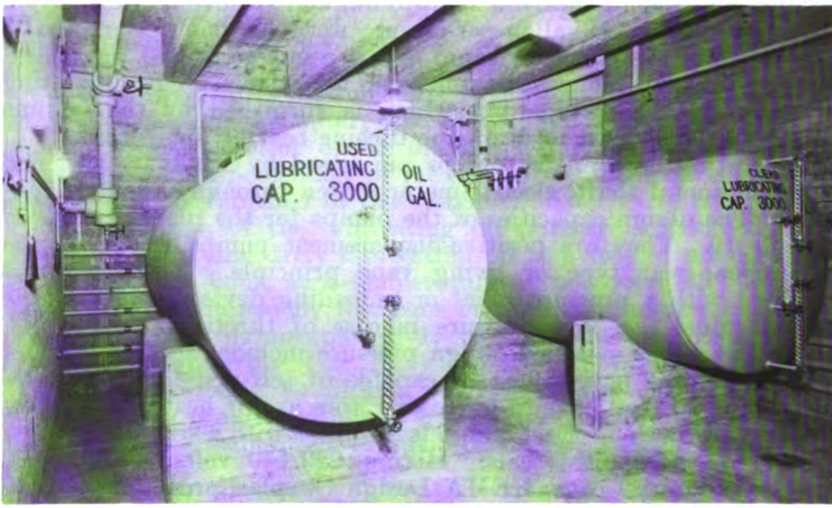


Figure 238.—*Lubricating oil storage room—Apalachta.*

equipped with strainers to prevent foreign matter from any source damaging the pumps. Filters are provided in the fill lines to the generator bearing reservoirs as an added precaution against pipe scale or other abrasive material entering the bearing.

INSULATING OIL SYSTEMS

A typical diagram of an insulating oil system is shown in plate 28, a typical list of operations performed by such a system appears in the early pages of this chapter, and table 11 lists pertinent data concerning these systems and associated equipment as installed in TVA projects.

Oil characteristics

Standard specifications for insulating oil for use in transformers and oil circuit breakers are used by TVA in purchasing this type of oil. The general requirements are that the insulating oil is straight-run mineral oil obtained from fractional distillation of crude petroleum, refined specifically for use as an insulating and cooling medium in oil-immersed transformers and circuit breakers; is free of water, sediment, foreign materials, and petroleum fractions which may be injurious to electrical equipment; and unless otherwise specified does not contain artificial oxidation inhibitors, dispersion agents, or other additives.

New insulating oil is required to meet the following specifications:

Color—2 maximum
Specific gravity at 60° F.—0.840–0.920
Flash point—266° F. minimum
Fire point—293° F. minimum
Viscosity, SSU at 100° F.—63 maximum
Pour point—minus 40° F. maximum
Neutralization number—0.05 maximum

Inorganic chlorides and sulfates—none
Free sulfur—none
Corrosive sulfur—No. 3 maximum
Dielectric strength at shipping point—26 kv. minimum

Briefly, the above characteristics are significant to the quality of the insulating oil as follows:

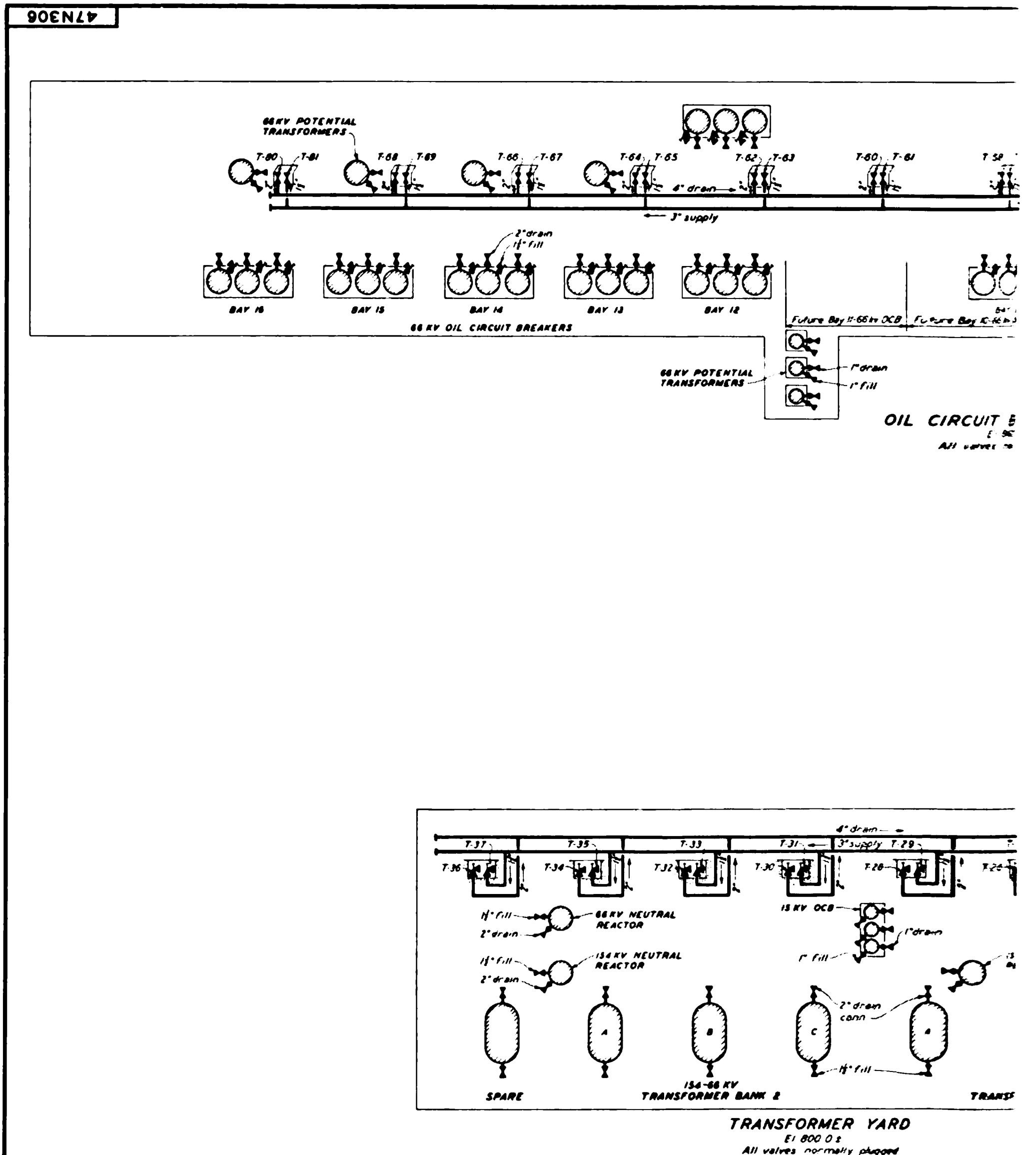
1. Color is an indication of the degree of refining and is checked by comparing the transmitted light through a stated amount of oil against the light transmitted through a color filter specified by the National Petroleum Institute. As an oil ages the color becomes darker and the color number increases.
2. Specific gravity is of minor importance.
3. Flash and fire points are checked by heating the oil in an open cup, passing a small gas flame over the cup, and noting the temperatures at which the oil vapors flash and at which the oil ignites. This test assures that no low-burning-point fractions of the crude oil are present.
4. Viscosity is measured at a given temperature by counting the seconds required for the oil to flow by gravity through a specified orifice. Viscosity is a measure of the ability of the oil to flow, and it is evident that the lower viscosity oils have superior cooling ability.
5. Pour point is the lowest temperature at which the oil will flow when chilled. This test assures that no waxes remain in the oil.
6. Neutralization number is the number of milligrams of potassium hydroxide required to neutralize the acids present in one gram of oil. As the oil ages, part of the deterioration products appear as acids, and the neutralization number is a detector of these acids.
7. Corrosive sulfur is detected by heating a polished strip of copper in the oil and noting the degree of discoloration of the copper.
8. The dielectric strength (voltage breakdown test) is a detector of the presence of water in the oil. If arcing occurs between the 1-inch-diameter discs spaced 0.1 inch apart with the new oil in the test cup under 26 kv. or less, the oil is considered to be contaminated. The water which causes the low breakdown is removed by a filter press, and the oil is filtered or otherwise reconditioned if its dielectric strength drops to 25 kv.

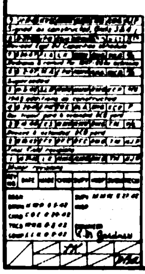
Transformers

Oil-immersed transformers are used for most TVA power system installations because of the high insulating qualities of oil, the high rate of heat transfer from the core and conductors to the oil, and the ease in obtaining adequate cooling surface. The most common type of installation is the self-cooled, oil-immersed transformer because of its great dependability and low maintenance cost. Fans with automatic thermostatic control are provided on the radiators for supplementary transformer capacity. Forced-air cooling for hydro generator transformers was first used at Hales Bar for the transformers for units 15 and 16, using pumps for forced circulation of oil through separate coolers.

Large oil-filled transformers are of either the "Conservator" or "Inertaire" type to prevent oil deterioration due to contact with the air. In the former type, the main tank is completely filled with oil and connected to a separate expansion tank provided with a breather. The relatively small surface of cool oil in contact with air in the Conservator type reduces the moisture and oxygen absorption.

At most of the plants the transformers are the Inertaire type and are equipped with facilities for maintaining a nitrogen atmosphere above the oil. Most of the manufacturers provide a cylinder of compressed nitrogen—connected to each transformer through an



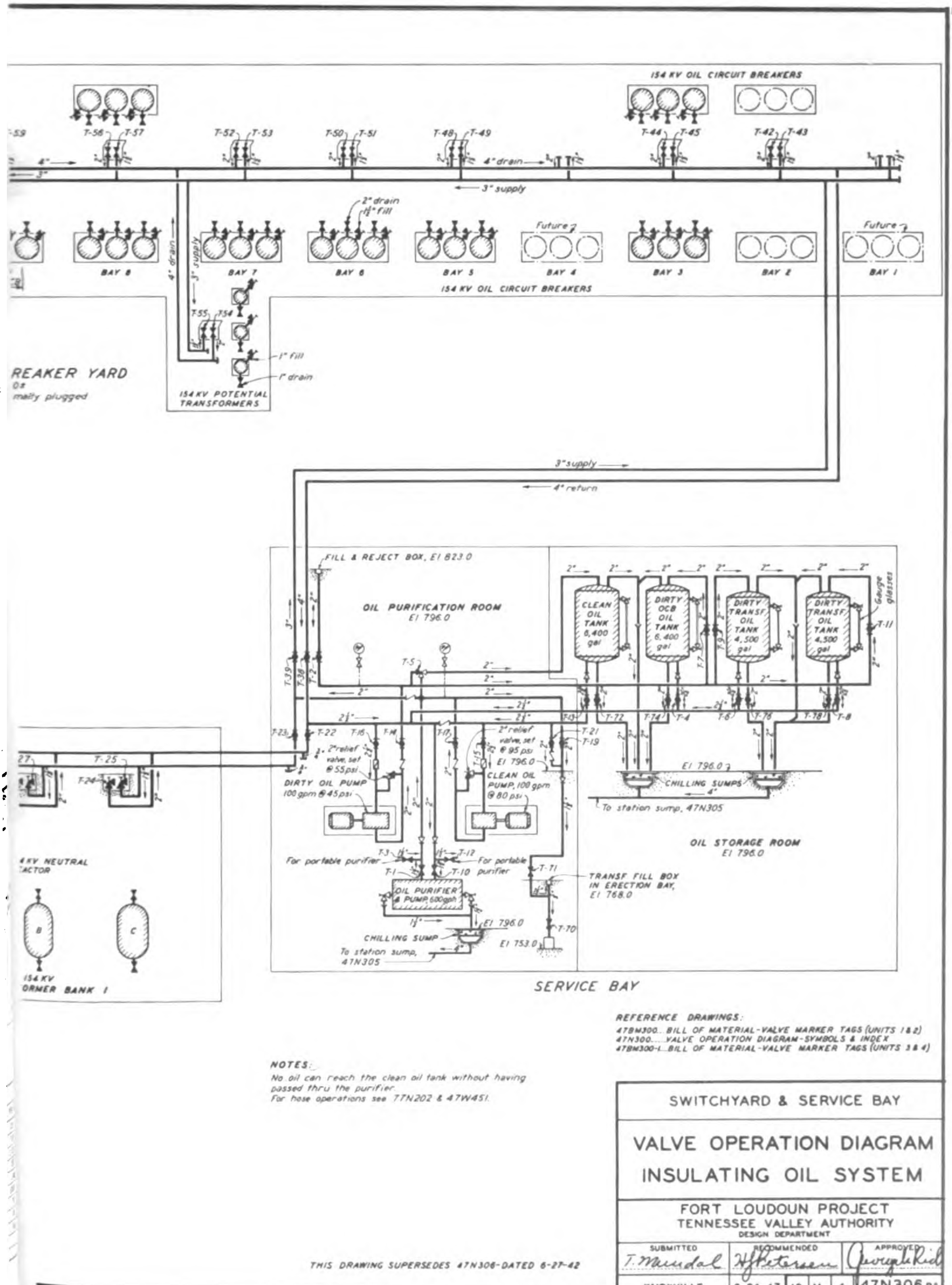


OPERATING POSSIBILITIES
SEE OPERATING INSTRUCTIONS

1 Filling dirty oil tanks from outside fill box by gravity
2 Purifying oil from dirty oil tanks and transferring to clean oil tank, using purifier pumps
3. Flushing headers with clean oil, using clean oil pump
4 Filling transformers or oil circuit breakers from clean oil tank, using clean oil pump
5 Emptying transformers into the appropriate dirty oil tank, using dirty oil pump, or oil circuit breakers into the appropriate dirty oil tank by gravity
6 Purifying oil in a transformer or oil circuit breaker by circulating thru purifier using purifier pumps
7 Circulating oil in any tank thru purifier
8 Using portable purifying equipment for yard service.
9 Filling any electrical equipment in service bay erection bay by gravity or using clean oil pump.
10 Removing oil from system, using dirty oil pump.

EQUIPMENT OIL CAPACITIES

NO. UNITS	NAME	GAL PER UNIT
1	15 kv oil circuit breaker	530
3	154 kv (single phase) transformers	7,854
8	154 kv oil circuit breakers	5,733
2	154 kv neutral reactors	295
3	154 kv potential transformers	246
4	154-66 kv (1 phase 3 winding) transf	6,5[illegible]
6	66 kv oil circuit breakers	[illegible]
7	66 kv potential transformers	[illegible]6
1	66 kv neutral reactor	64[illegible]


154 KV OIL CIRCUIT BREAKERS
4" drain
3" supply
2" drain
1½" fill
Future
BAY 8
BAY 7
BAY 6
BAY 5
BAY 4
BAY 3
BAY 2
BAY 1
154 KV OIL CIRCUIT BREAKERS
1" fill
1" drain
154 KV POTENTIAL TRANSFORMERS
REAKER YARD
3" supply
4" return
FILL & REJECT BOX, El 823.0
OIL PURIFICATION ROOM
El 796.0
CLEAN OIL TANK 6,400 gal
DIRTY OCB OIL TANK 6,400 gal
DIRTY TRANSF. OIL TANK 4,500 gal
DIRTY TRANSF. OIL TANK 4,500 gal
Gauge glasses
2" relief valve, set @ 55 psi
DIRTY OIL PUMP 100 gpm @ 45 psi
2" relief valve, set @ 95 psi
El 796.0
CLEAN OIL PUMP, 100 gpm @ 80 psi
El 796.0
CHILLING SUMPS
To station sump, 47N305
OIL STORAGE ROOM
El 796.0
For portable purifier
For portable purifier
OIL PURIFIER & PUMP, 600 gph
CHILLING SUMP
To station sump, 47N305
El 796.0
El 753.0
TRANSF FILL BOX IN ERECTION BAY, El 768.0
SERVICE BAY
154 KV
ORMER BANK 1
REFERENCE DRAWINGS:
47BM300...BILL OF MATERIAL-VALVE MARKER TAGS (UNITS 1 & 2)
47N300.....VALVE OPERATION DIAGRAM-SYMBOLS & INDEX
47BM300-1...BILL OF MATERIAL-VALVE MARKER TAGS (UNITS 3 & 4)
NOTES:
No oil can reach the clean oil tank without having passed thru the purifier.
For hose operations see 77N202 & 47W451.
SWITCHYARD & SERVICE BAY
VALVE OPERATION DIAGRAM
INSULATING OIL SYSTEM
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-24-47
47N306
THIS DRAWING SUPERSEDES 47N306-DATED 6-27-42

automatic reducing valve—to admit nitrogen to the transformer when the oil pressure drops to near atmospheric pressure, and an automatic relief valve to discharge nitrogen from the transformer when the pressure increases to several pounds above atmospheric. It is specified that sufficient nitrogen be furnished to purge the air from the gas space. Experience with the nitrogen-filled transformers indicates that under normal conditions the oil requires no attention for periods of several years.

Core, coils, tanks, and other parts are specified to be in conformity with standard manufacturers' practice. Oil drain, filling, and filtering connections are provided with valves and fittings for connecting, by means of flexible hose, to the station piping. Temperature of the top oil is indicated by a dial-type thermometer on the case.

Oil is purchased with the transformer to TVA specifications, and the same oil is used for transformers and circuit breakers. Makeup and spare quantities of oil are purchased directly from the refineries. Shipment is usually made with nitrogen in the transformer tanks, and the oil is shipped in tank cars. After the transformer is in place on its foundation, the nitrogen is withdrawn, and the oil is introduced under vacuum after being filtered.

Circuit breakers

A dead-tank oil circuit breaker, commonly installed for outdoor use, consists of a steel tank partially filled with oil, through the cover of which are carried porcelain or composition bushings. Contacts at the bottom of the bushings are bridged by a conducting crosshead carried by a wood or composition lift rod which, in early designs, drops by gravity, thus opening the breaker. Accelerating springs are specified by TVA to increase the rate of opening. In many designs, two bushings and one crosshead give two breaks per pole, while in some the contacts and crossheads are designed to give four, six, or more breaks per pole with a reduction in the length of stroke to give adequate arcing distance.

The breaker is arranged to be closed normally by remote electric control by means of either a solenoid-, a pneumatic-, or a spring-operated mechanism. The breaker is arranged to be opened normally by remote electric control by means of springs and gravity, or by springs only, after being released by a trip coil. A manual-tripping lever or button is also provided for tripping the breaker.

Multitank breakers with each pole in a separate tank are used. The tanks are each equipped with a gage to indicate the top level within the allowable operating range. A vent with oil-separating features is provided on the tank to permit the escape of gases generated by the arc and prevent the escape of the entrained oil.

Periodic checks of oil and breaker operation and condition are performed.

Purification equipment

Insulating oil purification equipment of either portable or stationary type as required is provided at most power stations. Portable purification equipment is usually supplied from a nearby large plant for small remote-controlled stations. This equipment is specified to have a purifying capacity of not less than 600 gallons per

hour. A filter press which raises the capacity to 900 gallons per hour is added to remove the colloidal carbon from the oil. A stationary insulating oil purifier is shown in figure 236 and a portable purifier in figure 239.

The insulating oil purifying unit consists of a centrifuge, centrifuge motor, two motor-driven pumps, electric heaters, filter press, automatic temperature control, thermometers, gages, meters, screens, valves, piping, electrical equipment, and other accessories for satisfactory operation. With this unit an electric filter paper drier is furnished having sufficient capacity to dry thoroughly not less than 240 sheets of filter paper in 1 operation. The drying oven (fig. 240) is complete with thermometers, electric heaters, and regulating switches. Complete insulating oil purifier procurement specifications are included in appendix B.

The centrifuge of the insulating oil purifier discharges into a collecting and deaerating tank. It is capable of purifying insulating oil containing 1,000 volumes of water in 1 million of oil in a single pass, so that the purified oil contains no more than 5 volumes of water in 1 million of oil. The purified oil shall then have a dielectric strength of not less than 30 kilovolts when tested in a standard cup with 1-inch-diameter discs spaced 0.1 inch apart. Tests on purifier capacity are conducted by the manufacturer and witnessed by TVA inspectors, and test reports are submitted for TVA engineers' approval.

Used insulating oil having unsatisfactory characteristics for further safe use after normal centrifugal purification is re-refined to extend the life of the oil. Four insulating oil re-refining units of the continuous, bulk-refill automatic type, each having a capacity of 300 gallons per hour, installed at the Power Service Building at

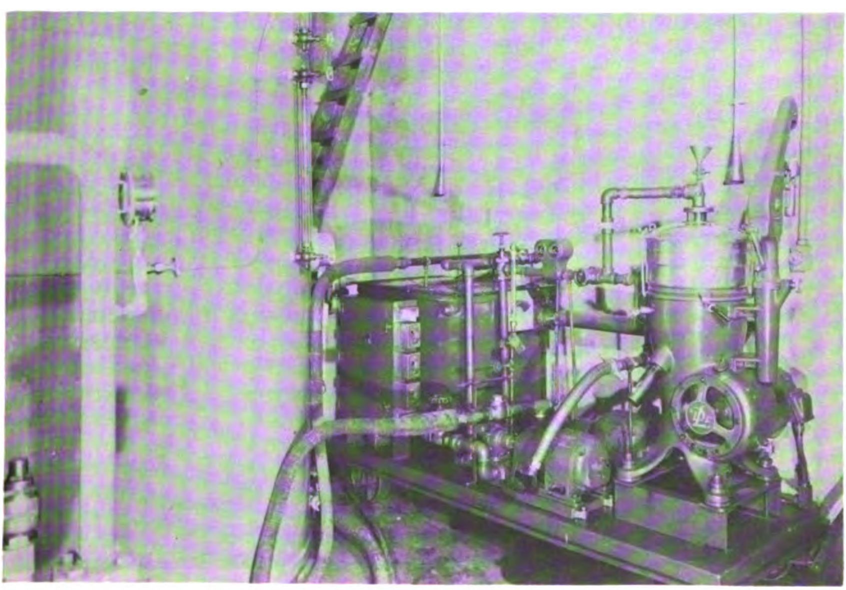


FIGURE 239.—*Portable oil purifier.*

Wilson Reservation are shown in figure 241. These units, manufactured by the Honan-Crane Corp., are arranged for operation either in parallel or in series. Under normal operation the oil to be acid-corrected will be transferred into one dirty-oil batch tank and passed through the refiner to the clean-oil batch tank. This oil is then pumped to the clean, acid-corrected oil tank in the yard.

In principle, the dirty oil passes into the insulated shell of the Honan-Crane refiner in which it is electrically heated and thermostatically controlled at a temperature between 130° and 180° F. The oil passes through a perforated metal basket and filter cloth bag into fuller's earth. All solid particles, such as carbon, dirt, sludge, etc., are removed by the straining action; and acids, lacquers, and other nonlubricants are held by the adsorbing action. The purified oil then passes through three layers of dense wool felt and a fine mesh screen to reach the outlet pipe.

TVA specifications for insulating oil re-refining equipment require an improvement in the characteristics of the oil as indicated in the following table:

Characteristic	Dirty oil	Refined oil
Dielectric strength	18 kv.	28 kv.
Neutralization number	0.5	0.05
Interfacial tension	12	35
Color	5	2
Steam emulsion number	60	35
Sediment, percent	0.2	Trace

The interfacial tension (the oil characteristic above not previously defined) is a measure of the presence of hydrophilic compounds which are formed as oxidation products as the oil ages. Oil in good condition will have an interfacial tension of 25 dynes per centimeter of ring circumference or over. An interfacial tension of 15 or under denotes some sludge present and oil no longer useful.

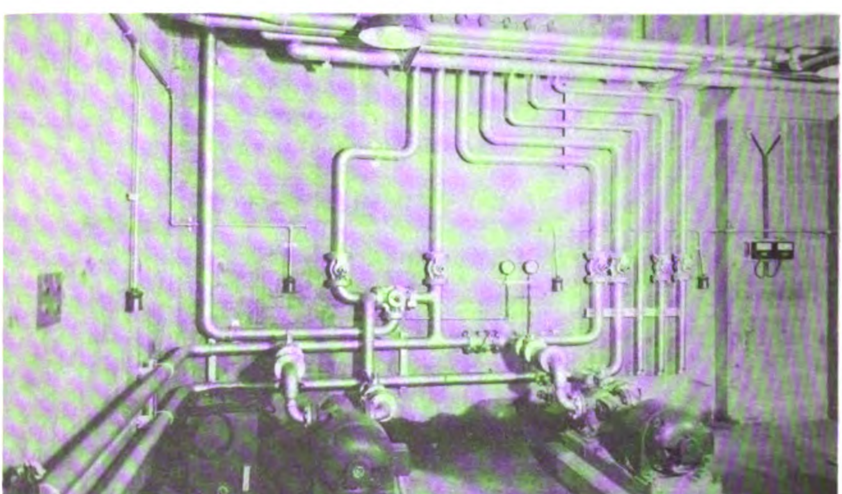
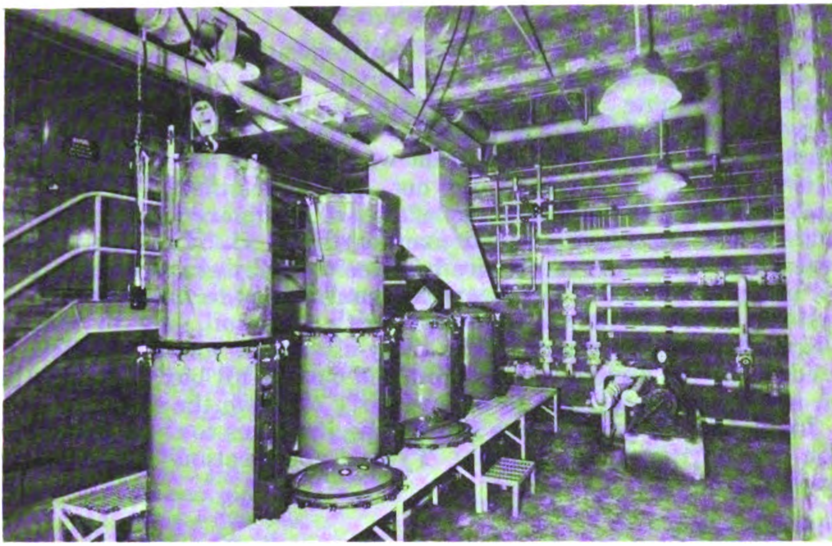


FIGURE 240.—*Insulating oil pump room—portable drying oven, at left, and oil tank level gages, at right—Watauga.*



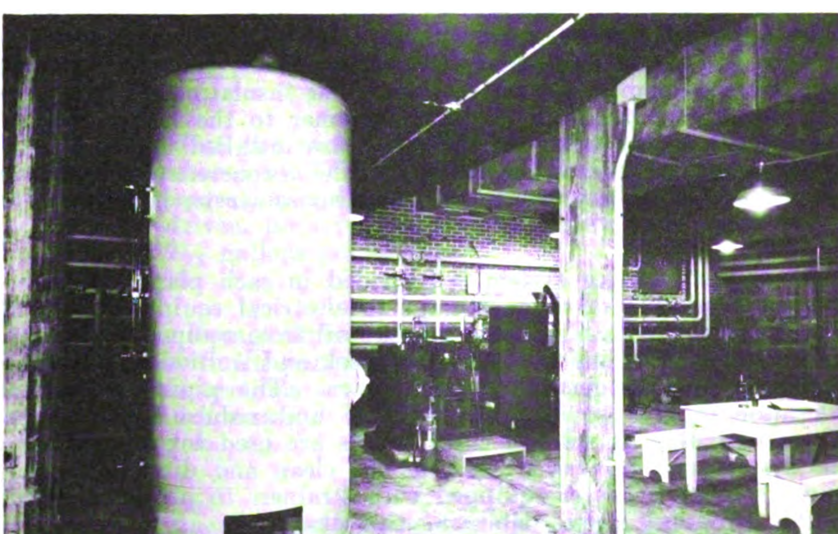


FIGURE 241.—*Oil purification—Power Service Building at Wilson Reservation—top view is left half of room and bottom view the right half.*

Pumps

Electric-motor-driven, positive-displacement pumps are provided to transfer the insulating oil as required. These are usually of 100-gallon-per-minute capacity or greater to hold the period of shutdown of the electrical equipment to a reasonable minimum during emptying or filling. An exception was Fort Patrick Henry project where the higher capacity did not appear justified, and two 56-gallon-per-minute pumps were installed. There are usually two oil pumps, one for clean oil and one for dirty oil. In some plants, where the equipment can be drained to storage by gravity, the dirty-oil pump is omitted. The clean-oil pump is used to flush the piping system, to fill electrical equipment with clean oil, and to remove clean oil from the system. The dirty-oil pump, where installed, is used to fill the dirty-oil tanks from the outside fill box, to drain the electrical equipment, and to remove dirty oil from the system.

Insulating oil pumps have similar specifications to those described for the lubricating oil pumps. Typical specifications are given in appendix B.

Storage tanks

One clean-oil tank with sufficient capacity to fill any piece of oil-insulated electrical equipment is provided at each plant. In addition, most power stations have two or more dirty-oil tanks, one for transformer oil and one for circuit breaker oil, due to the fact that oil from transformers and breakers is unclean to different degree and kind and requires somewhat different treatment.

These tanks are of welded steel construction. They have manholes for inspection purposes, either gage glasses or remote indicators to show liquid level, vent and overflow lines, drain connections, and separate supply and return lines. The insulating oil tanks are painted on the inside in a similar manner to the lubricating oil tanks. Where space is available, they are installed in the powerhouse; otherwise, they are installed outside on concrete saddles above ground or buried adjacent to the powerhouse service bay wall.

Piping

A complete piping system is provided in each plant for transferring insulating oil from storage to electrical equipment, draining equipment to storage, or circulating oil from equipment through the purifier. The exposed piping is steel, and embedded or underground piping is genuine wrought iron. The piping is welded wherever feasible to eliminate leakage and reduce friction loss. Three-way plug valves and check valves are used for flexibility in the system and to prevent mixing the clean and dirty oils. All pump suction lines are equipped with strainers to prevent foreign matter from any source damaging the pumps.

All exposed pipe is ASTM A 120 black steel and underground pipe is ASTM A 72 black wrought iron. Matching welding fittings are utilized throughout and most of the valves are of the lubricated plug type.

Valve boxes are provided near the electrical equipment in later switchyard piping layouts. Flexible hose is used to connect the system to the equipment when draining or filling is necessary. The hose is wire-lined and wire-inserted, of the combination suction and

discharge type, and has a specially treated synthetic-rubber lining. There is a flexible ball-joint fitting at the service valve to facilitate attachment.

TURBINE RUNNER HUB OIL SYSTEMS

Oil characteristics

A special heavy lubricating oil is required for runner hub lubrication which is not to be used for any other purpose or mixed with other oil. Specified requirements of runner hub oil, subject to approval of the turbine manufacturer, are as follows:

Color (NPA)—1¼ maximum.
Carbon residue, percent—0.02 maximum.
Flash point, ° F.—360 minimum.
Gravity, API—22–25.
Pour point, ° F.—minus 20 maximum.
Viscosity, SSU:
  At 40° F.—4200 approximately.
  At 100° F.—300–315.
  At 130° F.—130–140.
  At 210° F.—45–50.
Neutralization number—0.02 maximum.
Saponification number—0.06 maximum.
Steam emulsion number—32 maximum.
Corrosion—pass.
Demulsibility—1620.

The lubricating oil intended for use in the runner hub, which will be under water and subjected to mixing with water, must have satisfactory saponification, steam emulsion, and demulsibility characteristics to avoid undue deterioration of the oil.

Pumps

As mentioned in the early pages of this chapter, one portable pump was purchased by TVA to be moved from plant to plant as required for removal or replacement of runner hub oil. This is an electric-motor-driven, positive displacement, screw type pump with a capacity of 7½ gallons per minute.

Storage tanks

Two portable storage tanks were purchased also, to be moved from plant to plant with the portable pump. Each tank is provided with valved drain connections and has a capacity of 970 gallons. The pipe header and hose are drained into 55-gallon drums after operation of the system.

Piping

A typical runner hub oil system flow diagram is shown in figure 242. To eliminate too great a suction lift during removal of the oil from the runner hub, the portable pump is located near the draft tube access door. This point, however, is inaccessible for the portable storage tanks, which must remain on a higher floor. Similarly, while filling the runner hub from the storage tanks, the pump is located near the storage tanks. A permanent piping system, with sufficient versatility to perform these operations with the

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aid of flexible hose for connection to the runner hub, pump, and tanks, is ordinarily provided at each plant where required. The piping extends from the draft tube access gallery to some point where the portable storage tanks may be placed. Standard-weight black ASTM A 120 steel pipe is used with the necessary valves and welding fittings. Most of the valves in this system are the lubricated plug type.

SLUICE AND HEAD GATE OIL SYSTEMS

Oil characteristics

The same oil used for the generator, governor, and turbine lubricating oil is ordinarily used for the sluice and head gate oil systems. A lubricating oil having a viscosity of 1200 to 1500 SSU at 50° F. and 550 to 650 SSU at 75° F. is satisfactory.

Pumps

An electric-motor-driven, direct-connected, horizontal, screw- or rotor-type pump or pumps supply the pressure required for operation of the gates. The pump characteristics are standardized with a capacity of 20 gallons per minute against a total discharge pressure of 1,200 pounds per square inch. The pumps are designed to handle lubricating oil having a viscosity between 550 and 1500 SSU. All parts of the pump are built to withstand a momentary pressure of 2,000 pounds per square inch, and the pump is protected from excessive pressure by two relief valves—one set to relieve at 1,400 pounds per square inch and the other at 1,600 pounds per square inch.

These pumps have hardened steel rotors or screws in a hard alloy bronze casing or hard alloy bronze rotors or screws in a hardened steel casing. Screws or rotating elements are arranged so that they may be removed without disconnecting the motor or suction and discharge piping.

Pump motors are 440 volts, 3 phase, 60 cycles, squirrel cage, full-voltage start, high torque, low-starting current, NEMA Design B with splashproof frame. Motor synchronous speed is limited to 1,800 revolutions per minute.

Strip- or cartridge-type heaters are provided in the motors to prevent condensation and the resultant absorption of moisture by the windings. The heaters have sufficient capacity to raise the temperature of the motor windings approximately 5° C. above the ambient temperature with the motor at rest.

Where several sluice gates are involved, two pumps are provided, as shown in figure 243, page 508, one to serve as a standby unit. Sluice gate oil systems with two pumps are installed at Fontana, Cherokee, and Douglas. At Fontana a separate oil hydraulic system having one pump is installed to operate the slide gate upstream from the low level discharge outlet Howell-Bunger valves. One pump is installed to serve the sluiceway systems at Watauga, South Holston, Norris, and Boone.

As mentioned in the early pages of this chapter, Chatuge and Nottely each have two pumps—one 20-gallon-per-minute pump for

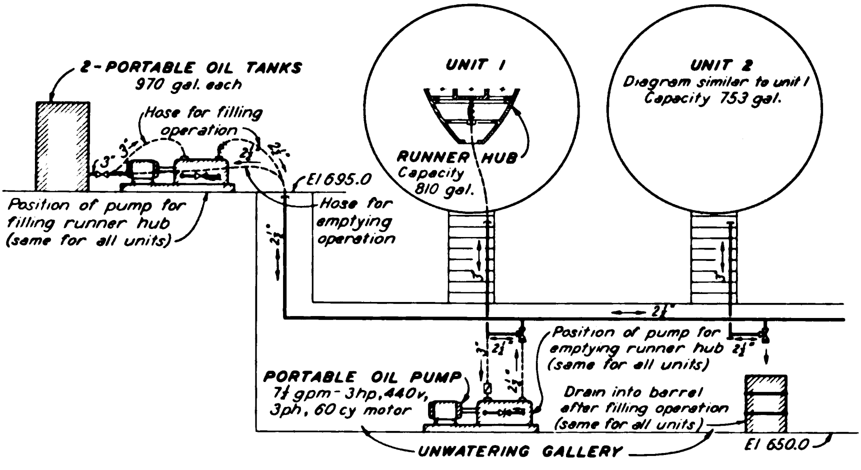


FIGURE 242.—*Runner hub oil system—Watts Bar.*

normal raising and lowering of the gates and a 120-gallon-per-minute pump for emergency closure of the gates by remote control. At these two projects the gates control the power conduit entrances and are designated head gates.

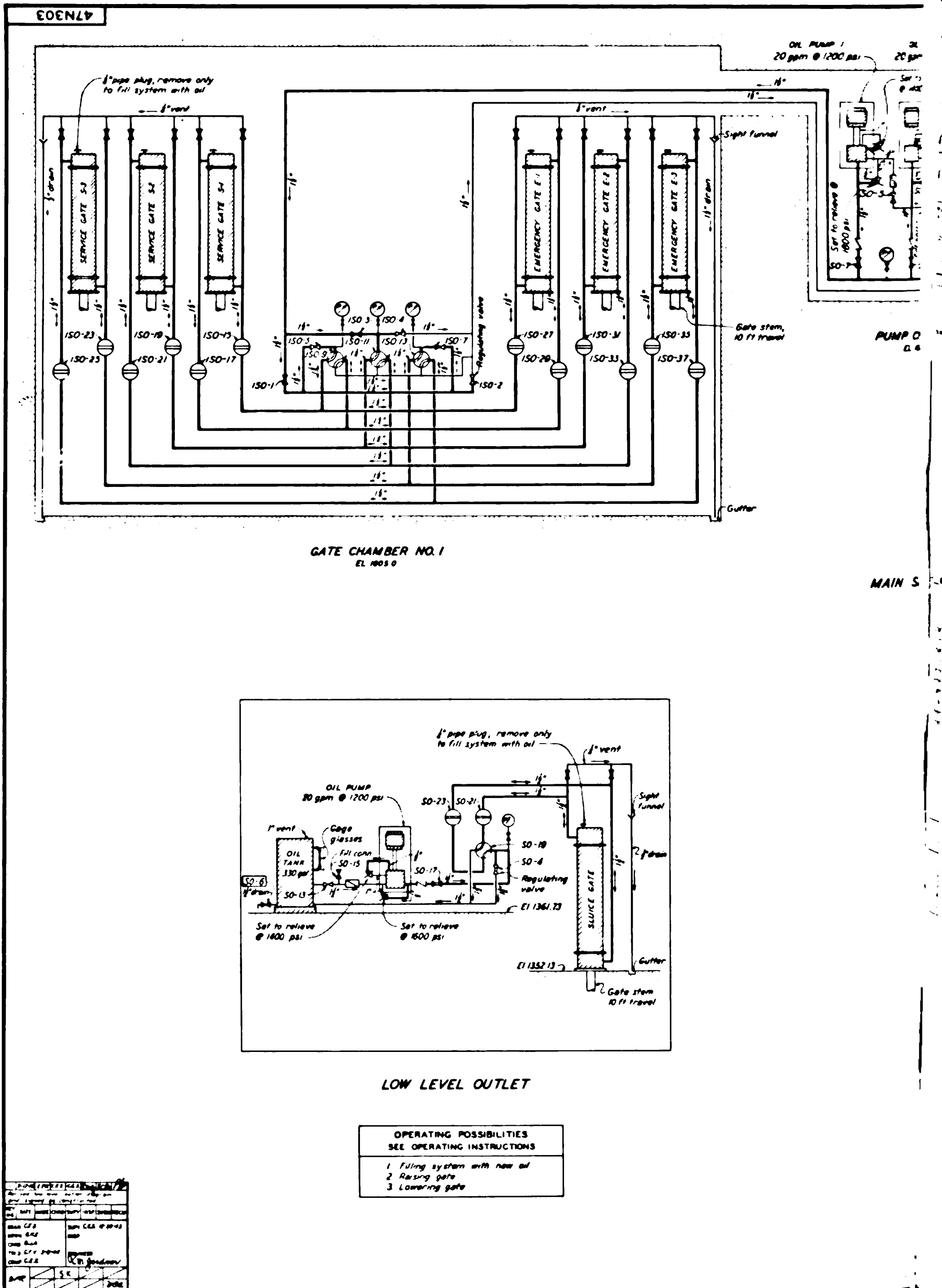
Typical sluice gate oil pumping unit specifications are given in appendix B.

Storage tanks

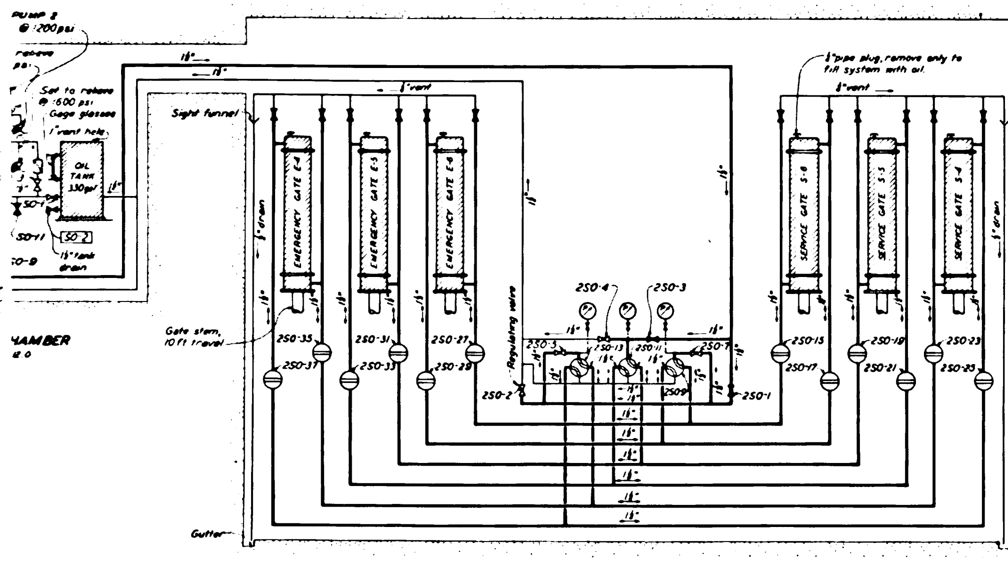
One steel tank of approximately 330-gallon capacity has been found sufficient to provide the necessary working capacity of each sluice or head gate oil system. Each tank is of the vertical-axis, cylindrical type with flat bottom and head and is vented to atmosphere at all times. Gage glasses on the tank show the oil level and there is a 1½-inch drain valve.

Piping

A typical sluice gate oil system diagram is shown in plate 29. Extra strong genuine wrought-iron or extra-heavy seamless steel pipe is used in the sluice gates oil system. Forged steel, 3,000-pound, screwed fittings, and 1,500- or 3,000 pound steel valves are used in the high-pressure portion of the system; and malleable-iron, 150-pound screwed fittings, and 150-pound bronze valves are used in the low-pressure portion. Directional high-pressure valves in the system are 3,000-pound lubricated steel plug valves, and 1,500-pound forged steel globe valves and horizontal ball-type check valves are used at the pump discharges. A 1,500-pound, 4-way valve (fig. 244, page 509) is used to transfer the pressure from one end to the other of the cylinder and vent the low-pressure side back to the storage tank. Individual pressure lines are valved to prevent accidental operation of the gates and to enable the operator to operate either the service or emergency gate in case where two gates are installed in series.



OIL PUMP 1
20 gpm @ 1200 psi
Sight funnel
Gate stem, 10 ft travel
Gutter
SERVICE GATE S-3
SERVICE GATE S-2
SERVICE GATE S-1
EMERGENCY GATE E-1
EMERGENCY GATE E-2
EMERGENCY GATE E-3
Regulating valve
GATE CHAMBER NO. 1
MAIN S
OIL PUMP
Oil tank
Gage glasses
Fill conn
Set to relieve @ 1600 psi
Set to relieve @ 1500 psi
Regulating valve
SLUICE GATE
Gate stem 10 ft travel
LOW LEVEL OUTLET
OPERATING POSSIBILITIES
SEE OPERATING INSTRUCTIONS
1 Filling system with new oil
2 Raising gate
3 Lowering gate



GATE CHAMBER NO. 2

EL 1605.0

PILLWAY

Start and stop push button control stations for pumps are located in gate chambers 1 and 2, and in pump chamber.
Only one oil pump is required for operating gates, other pump is standby for emergency use.
Light weight lines indicate return or drain lines.
Heavy weight lines indicate high pressure lines.

OPERATING POSSIBILITIES SEE OPERATING INSTRUCTIONS
1 Filling system with new oil 2 Raising service gates 3 Lowering service gates 4 Raising emergency gates 5 Lowering emergency gates

REFERENCE DRAWINGS:
47BM300... BILL OF MATERIAL - VALVE MARKER TAGS
47N300 ... VALVE OPERATION DIAGRAM - INDEX & SYMBOLS

OUTLET WORKS MAIN SPILLWAY AND LOW-LEVEL OUTLET				
VALVE OPERATION DIAGRAM SLUICE GATES OIL PRESSURE SYSTEM				
FONTANA PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT				
SUBMITTED D P Roberts	RECOMMENDED H F Petersen			APPROVED George E Rich
KNOXVILLE	12-30-43	19	M	4 47N303 R1

PLATE 29

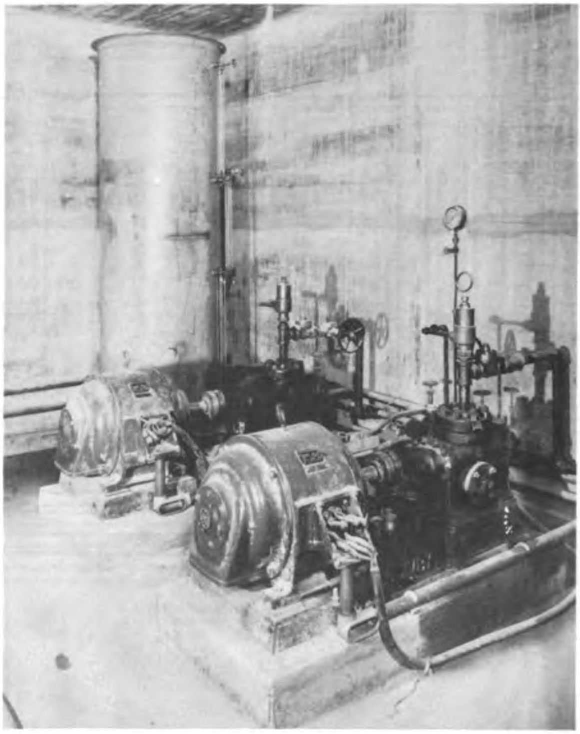


FIGURE 243.—*Sluice gate oil tank and pumps—Cherokee.*

Two spring-loaded relief valves are provided on the discharge of each pump to prevent damage to pump or piping in case the flow is stopped. One of these valves is set to relieve at 1,400 pounds per square inch and the other at 1,600 pounds per square inch. The relief valves return the oil to the storage tank or pump suction line.

Strainers in the pump suction line prevent scale or other foreign matter from entering the pump. A fill connection is provided in the pump suction line for use in filling the system from oil drums.

GENERATOR ROTOR JACKING

Oil Characteristics

The same oil used for the generator, governor, and turbine lubricating oil is used for generator rotor jacking.

Pumps

One portable, self-contained, hand-operated, high-pressure oil pump, as manufactured by the Watson-Stillman Co., is furnished for jacking by the generator manufacturer at each power station. The hand pump provided at Hiwassee is typical of other projects. This pump is a single-plunger type with a 1,500-cubic-inch reservoir and designed for a maximum pressure of 3,000 pounds per square inch.

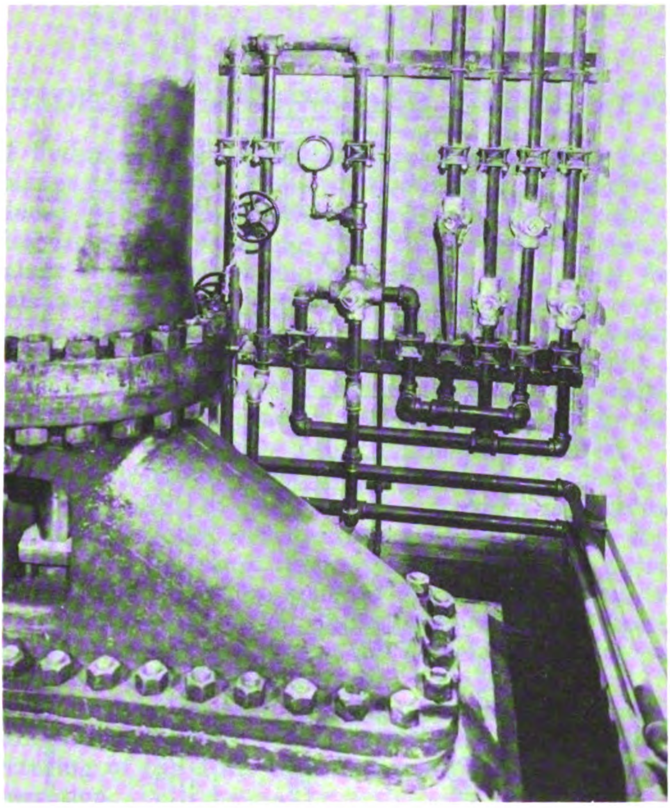


FIGURE 244.—*Valving station for spillway sluice gate oil system—Cherokee.*

Piping

A loop header, arranged for oil entry at one end and air entry at the other, is provided for oil and air supply to the combination generator brakes and jacks. An oil drain connection is provided near the oil supply end, and the air entry end is equipped with a gate valve to prevent oil entering the air system. Extra-strong steel or genuine wrought-iron pipe and 3,000 pound forged-steel fittings are used in the loop and supply headers, with high-pressure forged-steel valves.

An oil leakage header returns leakage oil from the jacks to a receptacle. This line requires standard-weight pipe and fittings. A typical jacking and braking system flow diagram is shown in figure 245.

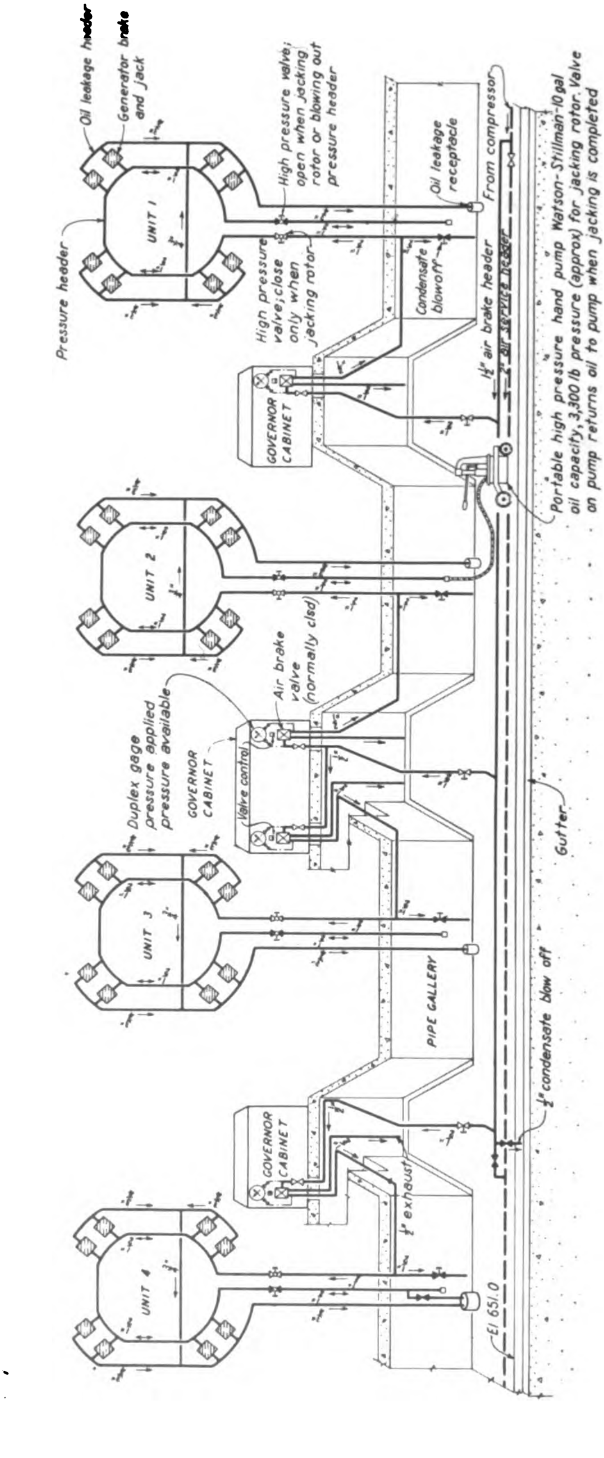


FIGURE 245.—*Generator oil jacking and air brake systems—Chickamauga.*

Chapter 11

DRAINAGE, UNWATERING AND FILLING SYSTEMS

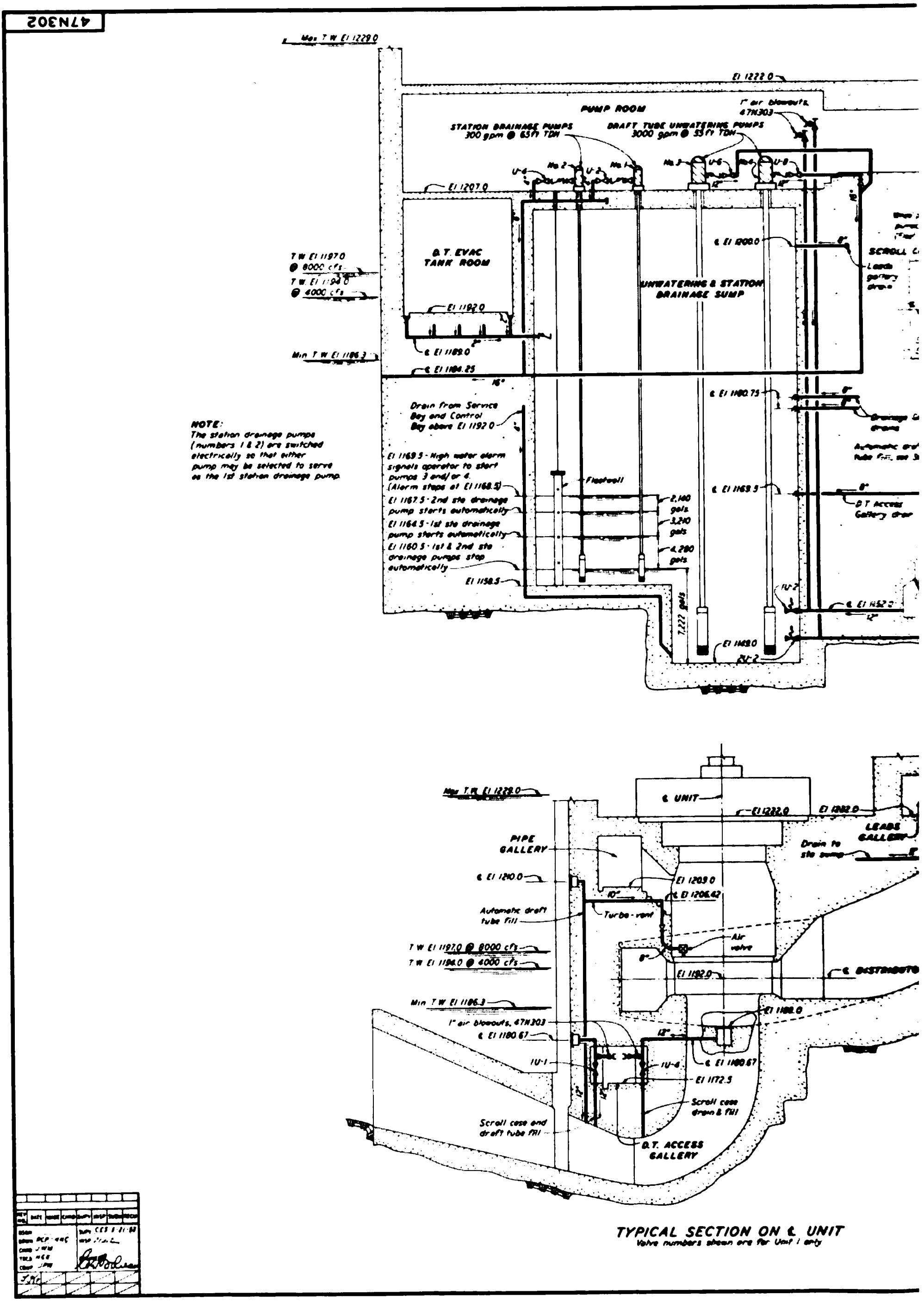
At all hydro power plants there are a great many sources of water leakage and waste. Some of these flows are intermittent and are produced by compressor cooling water, turbine pit drains, relief valve discharges, floor washing, drip traps, periodic piping blow-offs, strainer cleaning, deck and roof drains, etc. Other flows are continuous and emanate from pump gland leakage, compressor aftercooler cooling water, control valve stuffing box leakage, and leakage through the concrete structure and piping joints. Wherever this waste water is above maximum tailwater, it is carried in a separate piping system to gravity discharge at a point on the downstream side of the powerhouse below minimum tailwater.

Most of this drainage water is produced well below maximum tailwater and it must be pumped out. A sump is therefore provided in the powerhouse with maximum flow line below the lowest drain. Pumps in the sump discharge the water to a point below minimum tailwater. Because much of the drainage water is due to leakage, no accurate calculation can be made of the anticipated flow. The sizes of the sump and pumps are therefore a matter of judgment based upon previous installations.

Provision must be made at all plants for inspection and repair of the draft tube, turbine runner, and scroll case. This requires the unwatering of the draft tube and scroll case and their refilling before operation.

The draft tube and scroll case must be unwatered by pumping inasmuch as most of the water is at the lowest part of the powerhouse. If there were no leakage and time was of no consideration, this operation could be done by the station drainage pumps. But during repairs time is of the essence. This fact, together with the relatively great quantity of water to be pumped and the occasional excessive leakage, makes it imperative that special pumps be furnished for this service. Usually the drainage sump is made deep enough to drain the draft tubes, with one or more large draft tube unwatering pumps installed with the station drainage pumps. On some of the small and older large plants the two systems were not combined but kept separate.

Plate 30 shows a valve operating diagram for the drainage, unwatering and filling systems at Fort Patrick Henry project. This is typical of most systems. Appendix E includes operating instructions which are issued to operating personnel covering the drainage, unwatering and filling systems.



TYPICAL SECTION ON ℄ UNIT
Valve numbers shown are for Unit 1 only

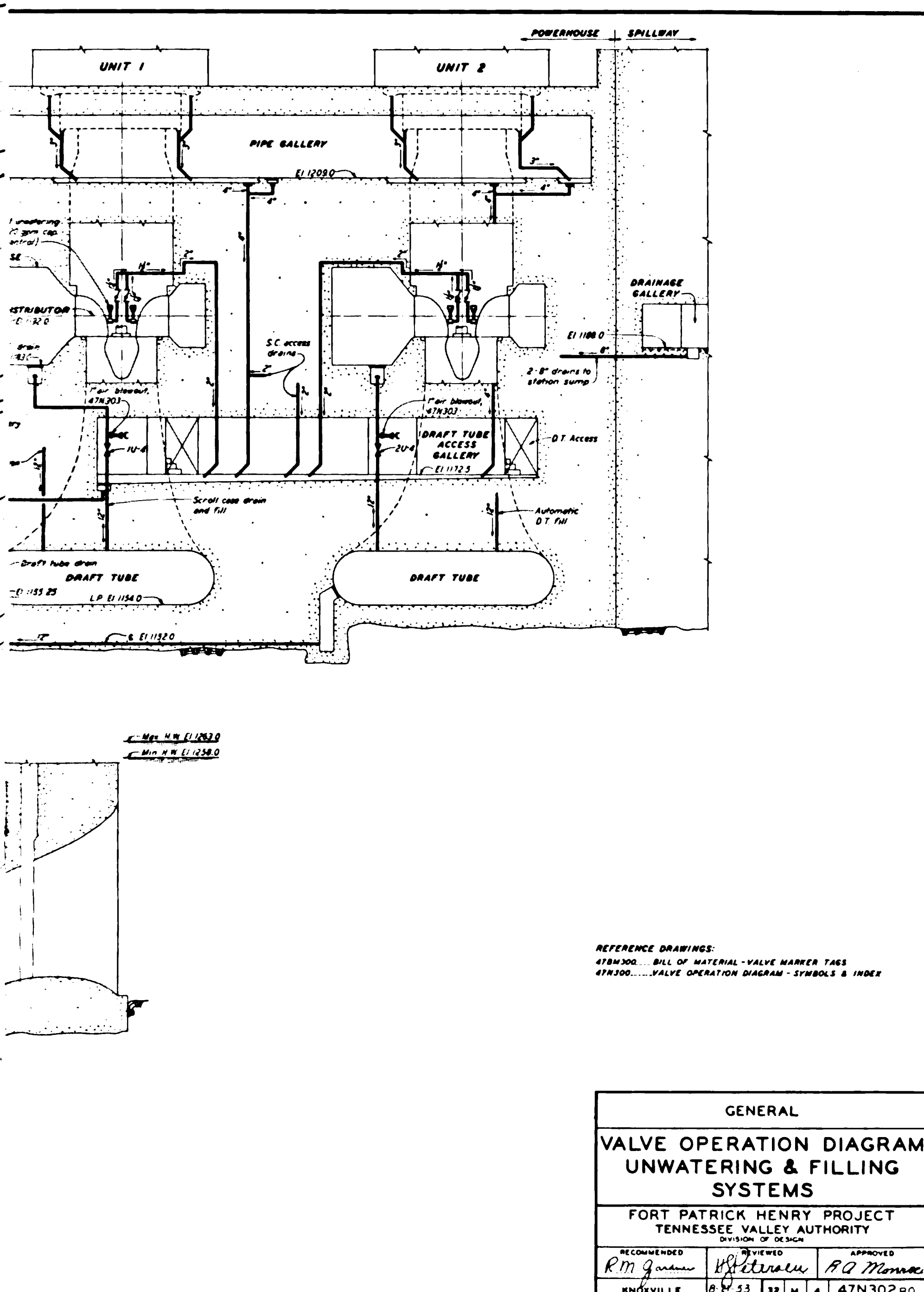

POWERHOUSE
SPILLWAY
UNIT 1
UNIT 2
PIPE GALLERY
DRAINAGE GALLERY
S.C. access drains
DRAFT TUBE ACCESS GALLERY
D.T. Access
Scroll case drain and fill
Automatic D.T. fill
DRAFT TUBE
DRAFT TUBE
REFERENCE DRAWINGS:
47BM300....BILL OF MATERIAL - VALVE MARKER TAGS
47N300......VALVE OPERATION DIAGRAM - SYMBOLS & INDEX
GENERAL
VALVE OPERATION DIAGRAM
UNWATERING & FILLING
SYSTEMS
FORT PATRICK HENRY PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
RECOMMENDED
REVIEWED
APPROVED
KNOXVILLE
47N302 RO

PLATE 30

STATION DRAINAGE

Collecting system and sump

A system of drainage piping connects all drain heads and waste connections to the station sump. Compressor and aftercooler cooling water discharges through funnels directly to the piping system. Pump gland leakage and condensate collected on the pump bases is piped directly to the nearest floor or gutter drain. Turbine pits are drained by either small sump pumps or water-operated eductors discharging directly into the drainage system. All galleries and the outer walls of rooms located below ground level have gutters cast into the concrete floors at the walls for carrying leakage or condensate to conveniently located gutter drains which are connected directly into the drainage system. Drains are combined where it can be done conveniently or they go direct to the station sump.

When the draft tube unwatering system is combined with the station drainage the former determines the depth and capacity of the sump. In those few cases where the systems are separate, the sump capacity, between pump control levels, is made about ten times the capacity per minute of one of the sump pumps. The pump capacity varies greatly depending upon the size of the plant and the anticipated inflow. At Nottely each of two pumps has a capacity of 30 gallons per minute whereas at Fontana one pump and one eductor each have capacities of 500 gallons per minute. The maximum flow line of the sump is below the lowest drain to ensure against backflow and flooding. Plate 31 shows a cross section of a typical sump and the unwatering pumps for the Boone project.

Table 12 lists the pumps and pertinent data covering the station drainage systems in TVA-built hydro plants and unit additions.

Roof and deck drains and other drains above maximum tailwater are combined or flow directly to tailwater. Roof, deck, and other drains exposed to rainfall are sized and spaced to carry away a rainfall of 4-inch-per-hour intensity.

At a few plants it was inconvenient to have the powerhouse septic tank effluent flow by gravity from an elevation above maximum tailwater. In every case this control elevation is well above normal tailwater but precautionary measures must be taken at some plants during rare excessive floods to prevent water backing up into the sanitary sewerage system. Under these conditions, the septic tank effluent is directed to the station sump and normal discharge cutoff by means of valves provided for this purpose and the settled sewage pumped to tailwater.

Pumping equipment

At most hydro plants, two pumps are installed in the sump, each having a capacity equal to the anticipated need, the second acting as spare or standby. At some of the high head plants a water-operated eductor operates continuously handling the normal drainage, and one pump is installed as standby or to handle any excess over the eductor capacity. All pumps are electric-motor-driven vertical units. Most of these are of the turbine type with semi-enclosed bronze impellers protected by a basket-type strainer. A few of the pumps are of the oil-lubricated type but most are water-

TABLE 12.—*Station drainage system data*

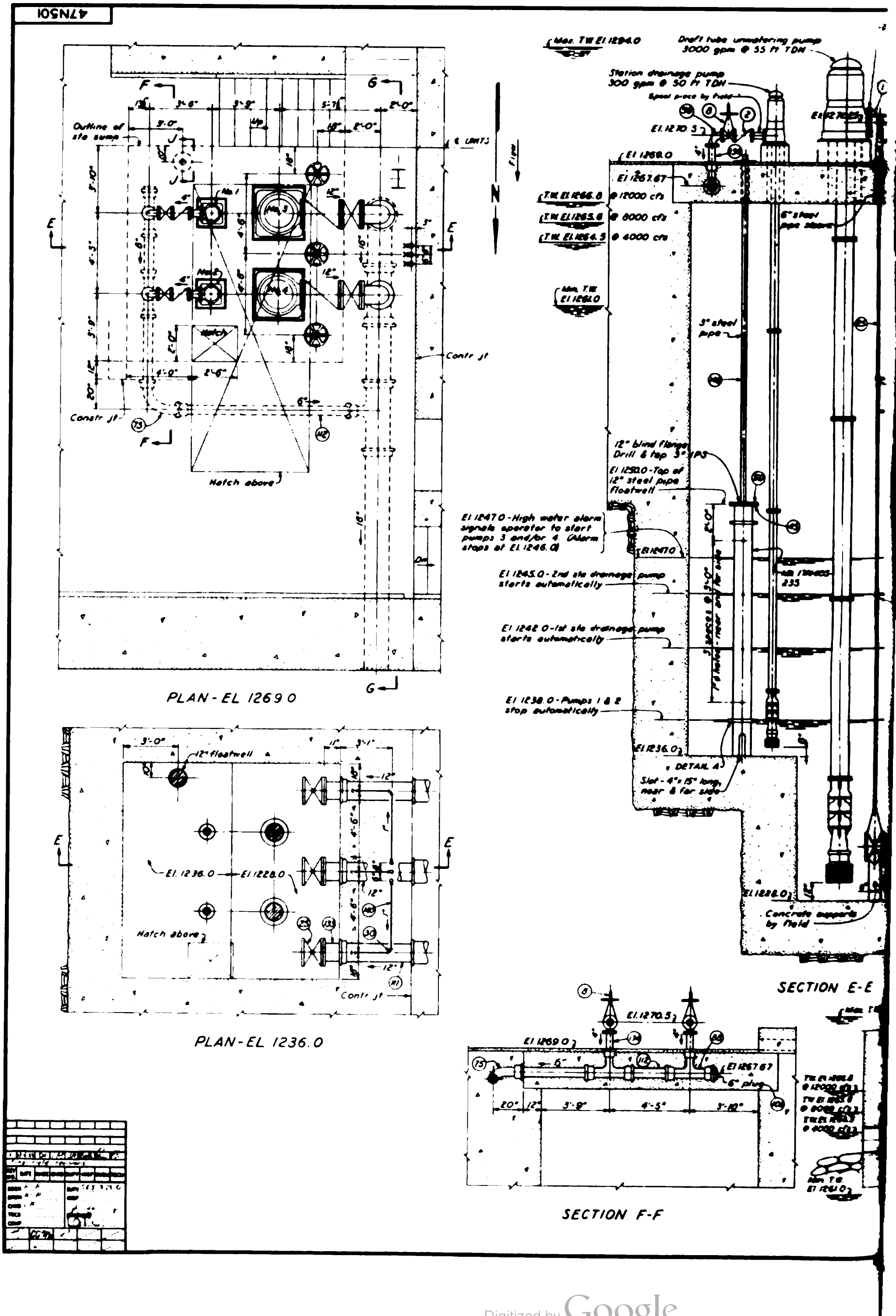
Project	Pumps				Eductors		Station drainage sump	
	Number	Capacity		Motor horse-power	Number	Nominal capacity, gallons per minute	Number	Working capacity [a]—gallons
		Gallons per minute	Total dynamic head, feet					
Norris	1	300	40	5	1	300	1	950
Wheeler	2	400	50	7.5			1	14,600
Pickwick	1	500	120	20			1	7,300
Guntersville	2	300	88	10			1	3,900
	[b] 1	50	35	1			1	120
Chickamauga	2	300	96	10			1	4,700
Hiwassee	1	300	17	3	1	333	1	710
	2	70	50	2			1	90
Watts Bar	2	300	40	7.5			1	9,200
Wilson:								
Auxiliary Unit	1	100	25	2			1	730
	1	700	35	10				
N. Service Bay	2	300	10	2			1	730
Units 9 and 10	2	150	12	2			1	960
Units 11 and 12	2	150	12	2			1	960
Unit 13	2	50	35	1.5			1	1,200
Unit 14	2	50	35	1.5			1	1,330
Units 15 and 16	2	150	35	3			1	960
Units 17 and 18	2	150	35	3			1	960
Cherokee	2	300	50	7.5			1	16,400
Douglas	2	300	50	7.5			1	16,400
Ocoee No. 3	1	300	20	3	1	300	1	7,200
Apalachia	1	300	20	3	[c] 1	300	1	7,400
Fort Loudoun	2	340	55	7.5			1	7,900
Kentucky	2	300	55	7.5			1	9,900
Fontana	1	550	40	10	1	500	1	6,500
Watauga	1	425	25	5	1	290	1	6,800
Wilbur Unit 4	2	50	40	1.5			1	220
South Holston	1	340	25	5			1	4,600
Hales Bar	2	300	85	10			1	6,800
Boone	2	300	50	7.5			1	7,500
Fort Patrick Henry	2	300	65	7.5			1	7,500
Chatuge	2	500	35	7.5			1	4,500
Nottely	2	28	40	0.75			1	80

[a] Volume in sump between levels where last pump starts and both pumps stop.
[b] Discharges drainage from air supply plenum.
[c] Also used for unwatering units.

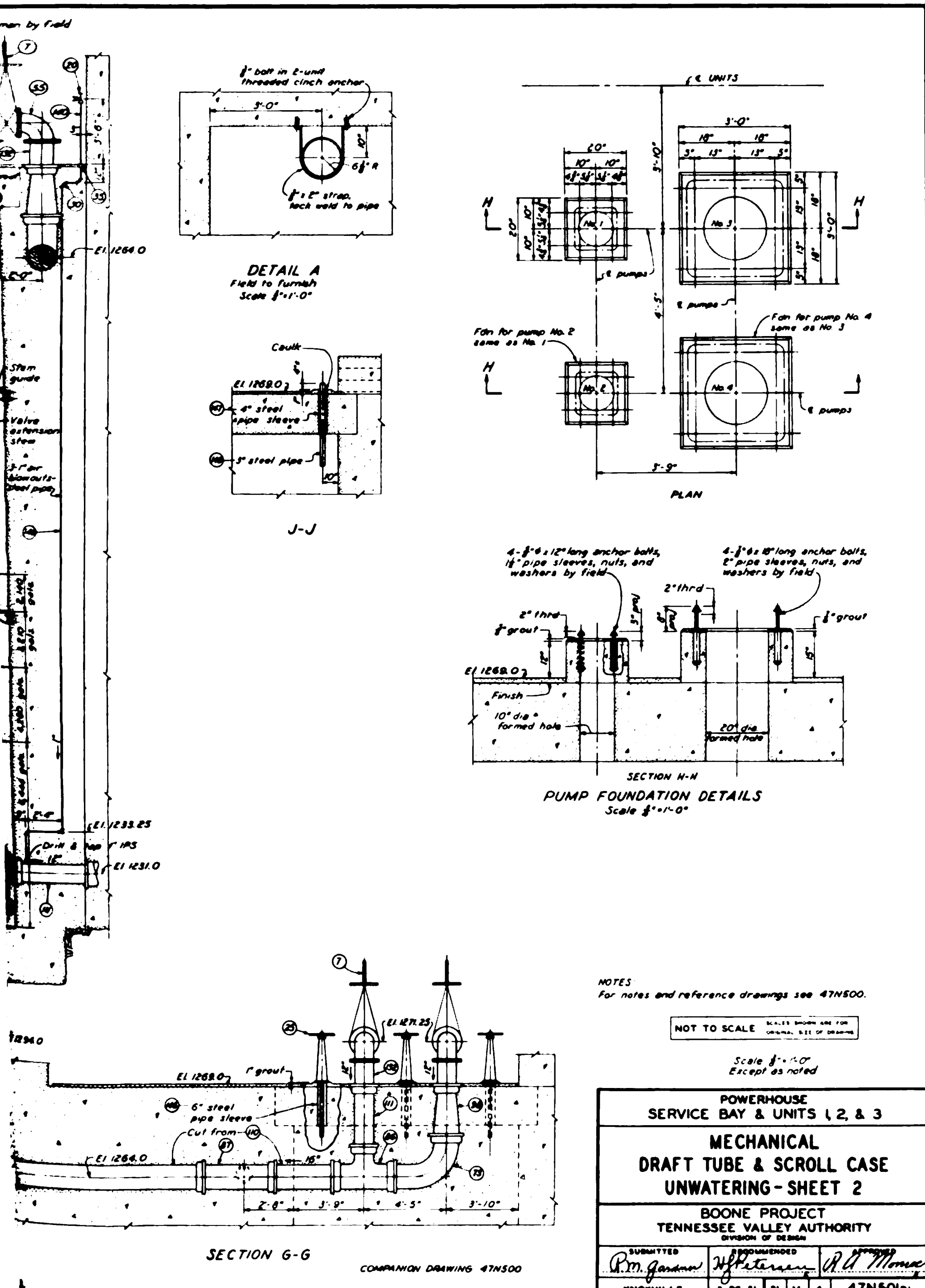
lubricated. The settings are relatively short and upon starting the bearings are wetted in such a short time that no damage has been reported because of dry bearing failure. The motors on all turbine-type pumps are of the dripproof, hollow shaft type, which permits easy adjustment to the impeller clearance so necessary for maximum capacity and efficiency on a semienclosed or open impeller. Typical station drainage pump specifications are included in appendix B. Figure 246 shows the station drainage pumps at Chickamauga.

At some of the high head plants, where adequate pressure is available at all head and tailwater conditions, a water-operated eductor is installed in the station sump to operate continuously discharging all normal drainage to tailwater. A motor-operated pump is always installed as a standby unit.

At the small hydro plants where there is a lesser amount of drainage water, small, duplex, motor-operated bilge pumps are installed. These are usually the self-contained type with both pumps, separate float switches, and a manhole all mounted on a common base plate. The motors are usually too small for the hollow shaft design and are of the solid shaft type with thrust bearing located between the pump base and the motor.



47N501
Outline of sta sump
Hatch above
Constr jt
Contr jt
Flow
PLAN - EL 1269.0
12" floatwell
El. 1236.0
El 1228.0
PLAN - EL 1236.0
Max. TW El 1294.0
Draft tube unwatering pump 3000 gpm @ 55 ft TDH
Station drainage pump 300 gpm @ 50 ft TDH
El 1269.0
El 1267.67
TW El 1266.8 @ 12000 cfs
TW El 1265.6 @ 8000 cfs
TW El 1264.5 @ 4000 cfs
Min. TW El 1261.0
3" steel pipe
6" steel pipe sleeve
12" blind flange Drill & tap 3" IPS
El 1250.0 - Top of 12" steel pipe floatwell
El 1247.0 - High water alarm signals operator to start pumps 3 and/or 4. (Alarm stops at El 1246.0)
El 1245.0 - 2nd sta drainage pump starts automatically
El 1242.0 - 1st sta drainage pump starts automatically
El 1238.0 - Pumps 1 & 2 stop automatically
El 1236.0
DETAIL A
Slot - 4" x 15" long, near & far side
El 1228.0
Concrete supports by field
SECTION E-E
El 1270.5
El 1269.0
El 1267.67
6" plug
SECTION F-F


DETAIL A
Field to furnish
Scale 3/4"=1'-0"
J-J
Caulk
El 1269.0
4" steel pipe sleeve
3" steel pipe
PLAN
℄ UNITS
No. 1
No. 2
No. 3
No. 4
℄ pumps
Fdn for pump No. 2 same as No. 1
Fdn for pump No. 4 same as No 3
4-3/4"⌀ x 12" long anchor bolts, 1 1/2" pipe sleeves, nuts, and washers by field
4-3/4"⌀ x 18" long anchor bolts, 2" pipe sleeves, nuts, and washers by field
2" thrd
1" grout
Finish
10" dia formed hole
20" dia formed hole
SECTION H-H
PUMP FOUNDATION DETAILS
Scale 3/4"=1'-0"
NOTES
For notes and reference drawings see 47N500.
NOT TO SCALE
Scale 3/8"=1'-0"
Except as noted
SECTION G-G
COMPANION DRAWING 47N500
El 1264.0
El 1233.25
El 1231.0
El 1271.25
6" steel pipe sleeve
POWERHOUSE
SERVICE BAY & UNITS 1, 2, & 3
MECHANICAL
DRAFT TUBE & SCROLL CASE
UNWATERING - SHEET 2
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
3-28-51
47N501R1

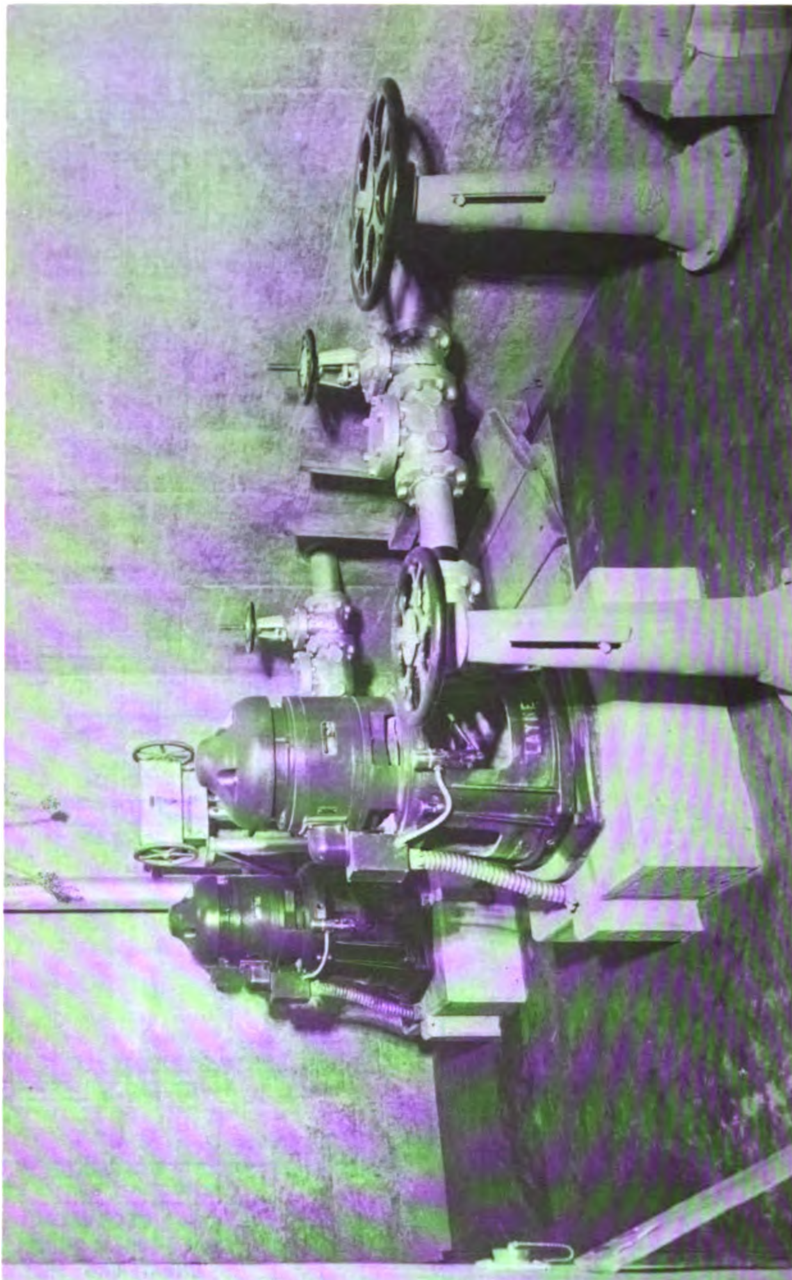


FIGURE 246.—*Station drainage pumps—Chickamauga.*

The pumps are all controlled by individual or multicontact float switches. There are three critical elevations where contacts are made by these switches. As water rises in the sump a contact is made at a moderately high level which starts one pump. With normal inflow the pump reduces the water to a low level in the sump where the float switch breaks contact and stops the pump and the level again rises due to inflow. When the water continues to rise above the moderately high level described above another contact is made at a high level which, through action of a relay, will start the second pump and sound an alarm in the control room. This alarm lets the operator know that either the inflow is abnormally high because it exceeds the capacity of the first pump or the first pump was not operating. In either case an operator should investigate and correct the trouble. When the two pumps operate they both pump until the water reaches the aforementioned low level where the float switch breaks contact to both pumps. The lead pump is changed periodically in order to equalize wear and be certain that one pump is in working order. This is done by changing operating levels at installations having separate float switches for each pump. Where a multicontact switch operates both pumps a manually operated transfer switch is used to change the lead from one to the other unit.

Piping

Black steel ASTM A 120 pipe is used for most of the embedded and exposed drain lines. Fittings for gravity pressure lines up to 6-inch size are black, cast-iron, screwed drainage type, and fittings 8-inch size and above are black steel welding or AWWA cast-iron bell and spigot type. Fittings for pump pressure lines are either cast iron, flanged or steel welding type. Most of the valves in the drainage systems are flanged IBBM gate and check valves.

DRAFT TUBE AND SCROLL CASE UNWATERING AND FILLING

Collecting system and sump

To inspect the internal parts of the turbine it is usually necessary to unwater the scroll case and draft tube. A valved drain line is always provided between the scroll case and the draft tube. After the head gates are closed this valve is opened and the scroll case and penstock drain to tailwater by gravity. An open vent line leads from a connection just downstream from the intake gate up to some elevation above maximum headwater elevation. This vent prevents a negative pressure in the penstock while draining, and vents air while filling. This vent does not have sufficient capacity to prevent penstock collapse if the wicket gates were fully opened while the intake gates were closed; hence, the scroll case drain. This drain connection is usually on the bottom to completely drain the case. If great care is taken the wicket gates may be opened slightly to aid in draining the penstock and scroll case.

The above operation drains water within the unit to the same elevation as tailwater. Depending upon the latter and the setting

498128 O—60——35

of the unit this elevation may be below or up onto the runner or even into the scroll case. The remaining water must therefore be removed by pumps before complete inspection can be made. All main-river plants and most of the high head plants are equipped with crane-operated draft tube gates located on the downstream face of the powerhouse and these gates must first be lowered. At a few plants no gates are provided because there is a high point in the tailrace above normal tailwater level (with no unit discharge) a short distance downstream from the powerhouse which serves the same purpose. The gate or the control elevation in the river isolates the draft tube from the river downstream and the unit may now be completely unwatered.

Each draft tube is equipped with a screened outlet close to the low point in the draft tube. At most stations a drain line connects this outlet to the station sump with gate valves located within the sump for controlling the flow. This connection therefore determines the depth of the station sump because it must be below the outlet drain elevation.

Large, electric-motor-driven, vertical, turbine-type pumps are installed in the sump adjacent to the station drainage pumps with discharge in a common pipe to tailwater downstream of either the gates or control point in the tailrace bed. Figure 247 shows the draft tube and scroll case unwatering pumps at the Fort Loudoun project. Typical unwatering pump specifications are included in appendix B.

At some of the plants where space limitations ruled and at two of the early main-river plants, the station drainage and draft tube unwatering systems are separate. In these cases, a separate well is provided for the draft tube unwatering pump. There is usually one pump per draft tube and it is located adjacent to the draft tube with a minimum of piping. Figure 248 shows this type of installation at Chatuge.

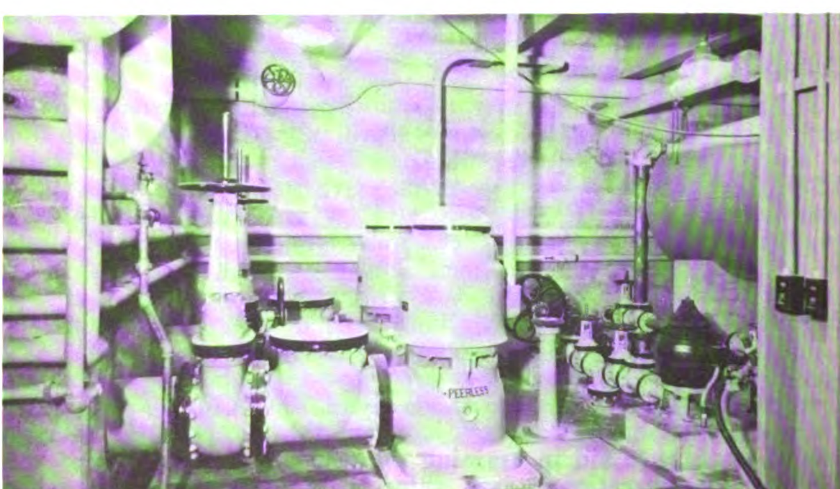


FIGURE 247.—*Two 5,000-gallon-per-minute capacity draft tube and scroll case unwatering pumps with smaller station sump pump at right—Fort Loudoun.*

In the early plants the draft tube screened outlet was installed on the bottom. However, trouble was experienced by these outlets becoming plugged from sediment and trash. By far the greater number of connections are therefore constructed as shown in figure 249. The screen is on the side about 12 to 18 inches up from the bottom and most of the solids in the water are carried past it. To further protect it from plugging, an air connection is provided between the screen and the control valve in the sump. Station air can be introduced to blow out any accumulation of clogging material.

Table 13 lists pumping equipment and pertinent data covering the draft tube and scroll case unwatering systems in TVA-built hydro plants and unit additions, and in Wilson units 1–8.

TABLE 13.—*Unwatering system data*

Project	Pumps				Eductors		Volume to be unwatered, gallons	Unwatering time,[a] minutes	Elevation tailwater level[b]
	Number	Capacity		Motor horsepower	Number	Nominal capacity, gallons per minute			
		Gallons per minute	Total dynamic head, feet						
Norris					1	2,000	[c] 19,300	10	826
Wheeler	[d] 2	4,500	50	75					
Units 1 and 2	[r] 4	2,500	60	50			976,000	[e] 255	507
Units 3–8	[r] 12	2,200	60	50			965,000	[e] 290	507
Pickwick	2	5,000	120	200			908,000	105	358.5
	1	500	120	20					
Guntersville	2	5 000	112	200			1,130,000	180	557
Chickamauga	2	5,000	125	200			1,246,000	180	634.2
Hiwassee:									
Unit 1	[f] 1	5,400	60	100	[f] 1	1,250	336,000	[g] 50	1,280.62
Unit 2							372,000	[g] 55	
Watts Bar	2	5,000	50	100			766,000	150	682
Wilson	[h] 2	2,500	40	40					
Unit 1							175 000	[j] 35	414.5
Unit 3							360,000	[j] 70	
Units 2, 4–8							330,000	[j] 65	
Units 9–18	[l] 10	8,000	32	40			330,000	[k] 40	
Cherokee	2	3,000	54	75			151,000	45	925
Douglas	2	3,000	54	75			192,000	60	873
Ocoee No. 3	[n] 1	300	20	3			23,400	[m] 70	1,115
Apalachia					1 [n] 1	1,000 300	29,000	[p] 25	840
Fort Loudoun	2	5,000	50	125			683,000	130	740
Kentucky	2	5,390	40	125			869,000	180	303.5
Fontana					1 1	2,000 1,000	114,000	[p] 25	1,710
Watauga	1	2,500	40	40			1,047,000	[q] 300	1,647.2
Wilbur Unit 4	1	1,500	32	20			80,000	50	1,587
South Holston	1	2,500	25	30			[q] 742,000	250	1,485
Hales Bar	2	5,400	65	125			808 000	125	597
Boone	2	3,000	55	60			116.000	30	1,264.5
Fort Henry	2	3,000	55	60			191,000	55	1,194
Chatuge	1	5,000	35	60			[q] 2,388.000	380	1,802
Nottely	1	1,070	35	15			[q] 122,000	95	1,605.5

[a] Assuming no leakage.
[b] Basis for computing unwatering volume. Normal or no flow level, whichever is applicable.
[c] Scroll case and penstock only.
[d] Can be used for scroll case and partial draft tube unwatering at all units.
[e] Using one regular draft tube unwatering pump and the two 4,500-gallon-per-minute scroll case unwatering pumps.
[f] Used by both units.
[g] Using pump and eductor.
[h] Draft tube unwatering caisson pumps.
[j] Using two caisson pumps only.
[k] Using one powerhouse pump and two caisson pumps.
[l] One pump serves each unit.
[m] Using station drainage pump.
[n] Also used for station drainage.
[p] Using two eductors.
[q] No draft tube gates. Portion of tailrace unwatered.
[r] Two pumps serve each unit.

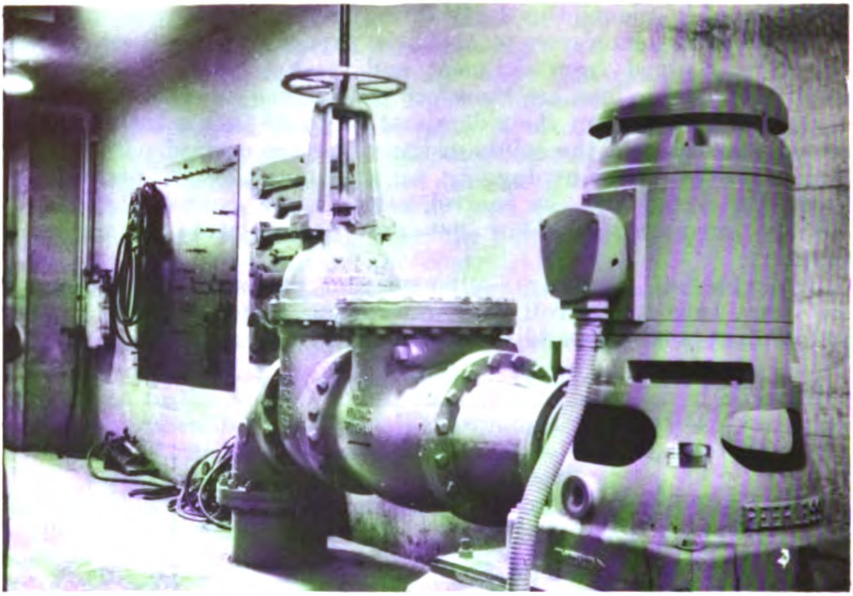


FIGURE 248.—*Well-type draft tube unwatering pump—Chatuge.*

Pumping equipment

If the volume of the draft tube and scroll case to be unwatered were the only consideration, the pump could be sized easily based upon a reasonable time for this unwatering. However, the unknown leakage through the gates or through the tailrace bed plus intake gate and draft tube leakage make the size selection one of judgment only. Usually two pumps are installed with size based upon that found satisfactory at similar operating plants. In some cases, one pump is installed with the provision for possible future addition of one more pump. This space requirement determines the plan size of the sump. It has been necessary at Hiwassee and Douglas to add one more pump because of excessive draft tube leakage. The size of pumps normally installed vary from 1,500 to 5,500 gallons per minute.

In all cases the pumps are the vertical-turbine or mixed-flow type and protected by a basket strainer. The impellers are of bronze and most are of the semienclosed type. Most of the pumps are of the water-lubricated type although some have oil lubrication. All motors have hollow shafts for the easy adjustment of pump impeller clearance. In most of the later plants the sump has been so located that the unwatering pumps may be pulled out as a complete unit by the powerhouse crane. This has required a hatch in the service bay floor but is a very convenient feature in time of trouble with the pump.

The draft tube unwatering pumps are controlled manually. Their size is so great in relation to the sump capacity that it would be impractical to use them for station drainage service, although they can be operated for this use in case of an emergency.

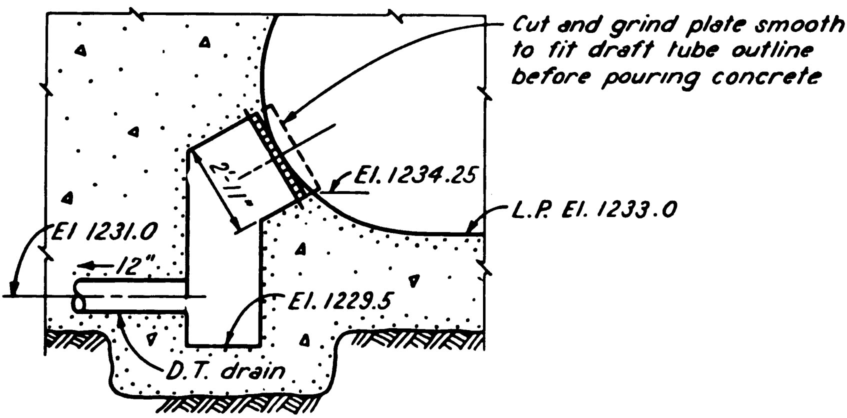


FIGURE 249.—*Typical draft tube drain inlet.*

Filling

After inspection or repairs have been made, the unit must be carefully filled with water before it can be operated. Even if the intake gates could be opened under the differential head existing with an empty penstock, the hydraulic shock to the rest of the equipment would be excessive.

Valved bypasses are provided around the intake gates at some of the high head plants having penstocks. At these plants it is customary to fill the draft tube of an unwatered unit through its drain valve by opening the interconnected draft tube drain valve of an adjacent operating unit. Similarly, by opening the scroll case drain valve of the unwatered unit, the scroll case will fill up to tailwater level. The scroll case drain and fill valves for one of the Chickamauga units are shown in figure 250. It is also possible in some plants by careful operation to fill an unwatered draft tube and scroll case by backflow through the station unwatering sump obtaining water by opening the draft tube drain of an operating unit. The draft tube gates may then be raised with equalized pressure on both sides. With the wicket gates closed and the scroll case drain valve closed, the intake gate bypass valve is carefully opened to complete filling of the penstock with the displaced air being vented to atmosphere through the previously mentioned vent on the downstream side of the intake gate. When the penstock is full, the pressure across the intake gates is equalized and they may be opened. The unit is then ready for operation.

At normal or low head hydro plants, the draft tube and scroll case filling line is usually taken from the tailwater side of the powerhouse. Opening the fill valve in this line permits the draft tube to fill (with the draft tube gates closed) and the scroll case is filled to tailwater level through the opened scroll case drain valve The draft tube gates may then be raised with equalized pressure on both sides. The scroll case drain and filling line valves are then closed and the head gates are cracked open to fill the remaining portion of the scroll case with the wicket gates in their closed position.

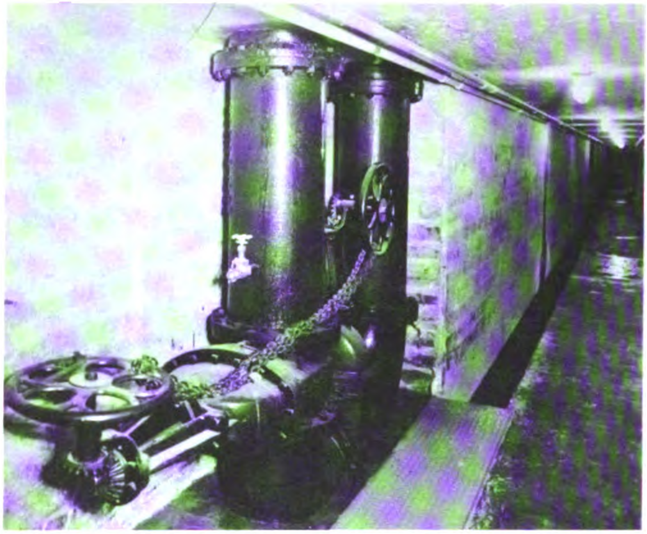


FIGURE 250.—*Scroll case drain and fill valves—Chickamauga.*

Piping

Cast-iron bell and spigot pipe and cast-iron AWWA bell and spigot fittings are used for all embedded unwatering piping. In most instances special cast-iron flange and spigot pipe is used for exposed piping, such as pump and valve connections. For air blowouts, which are usually 1-inch size, black wrought-iron pipe, ASTM A 72, and black malleable-iron fittings are used. Valves at the low head plants are usually iron body, bronze-mounted gates and checks. At high head plants 300-pound steel gate valves are used on high-pressure fill and drain lines.

WATER-JET EDUCTORS

Water-jet eductors are used for station drainage and draft tube and scroll case unwatering at some of the high head projects where water at sufficient pressure for their operation is available. Figure 251 shows one of these units at the Hiwassee project. The photograph clearly shows the simplicity of the unit which requires no motor and has no moving parts. They are operated continuously at a rate equal to the normal inflow to the sump. Operating water is obtained from a connection to the scroll case of the turbine. These units are used wherever feasible because of their low first cost, minimum space requirements, and low operating cost. Plate 32 shows the water-jet eductor unwatering system installed at the Fontana project.

SPECIAL DRAINAGE FACILITIES

In long penstocks a sump is usually provided to trap any heavy debris carried down the tunnel. When the system is unwatered it is necessary to unwater this sump preparatory to removing any accumulated debris. A portable, gasoline-engine-driven, self-prim-

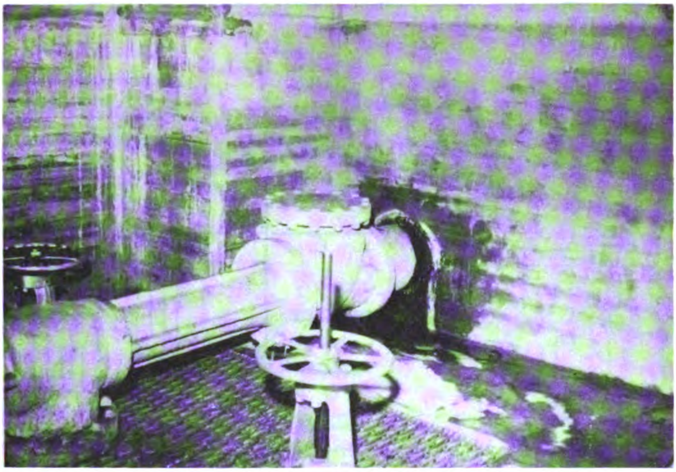


FIGURE 251.—*Unwatering eductor—Hiwassee.*

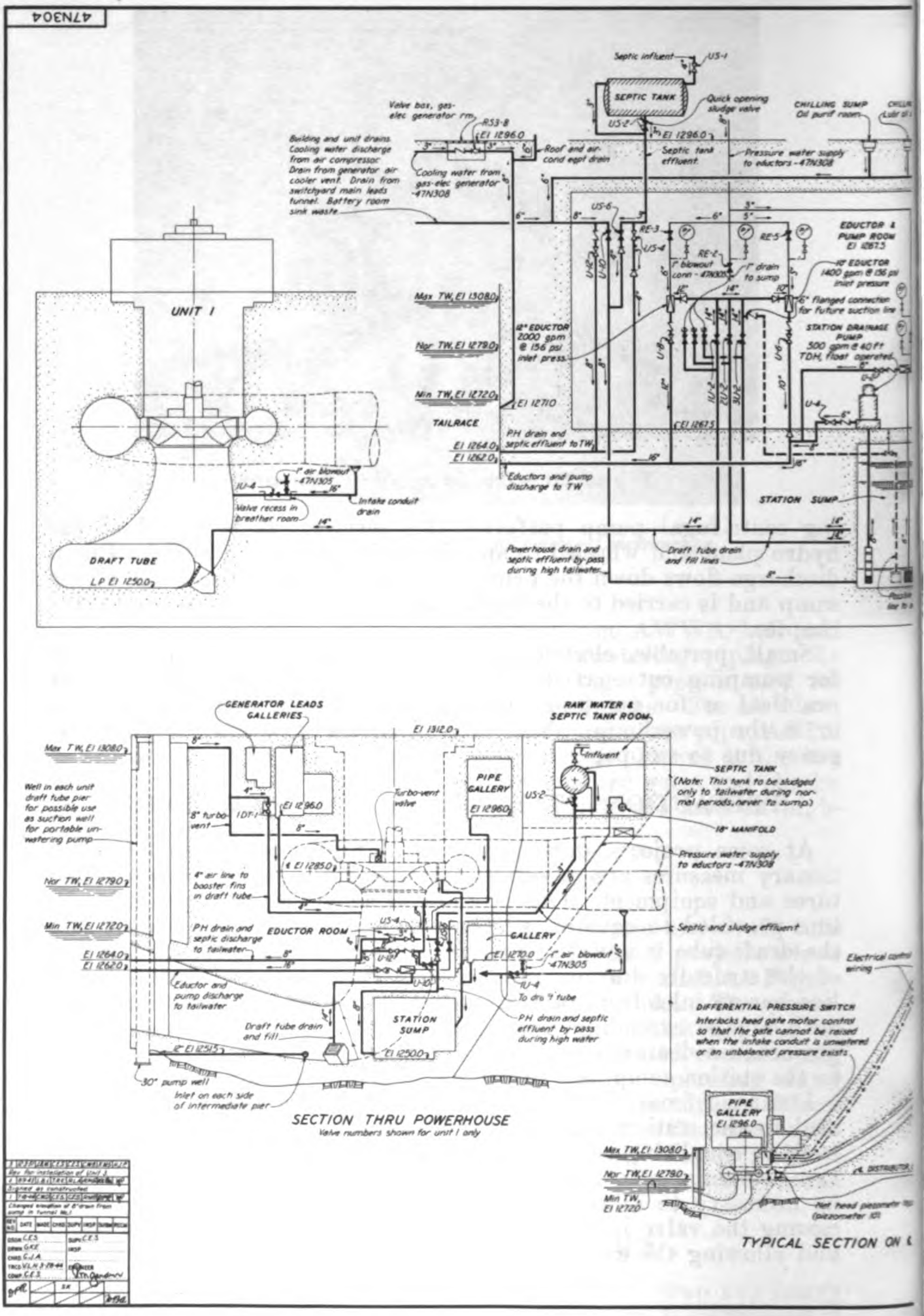
ing centrifugal pump performs this service. It is stored at the hydro plant and wheeled to and from the sump as required. Pump discharge flows down the penstock from the downstream side of the sump and is carried to the draft tube as described previously in this chapter.

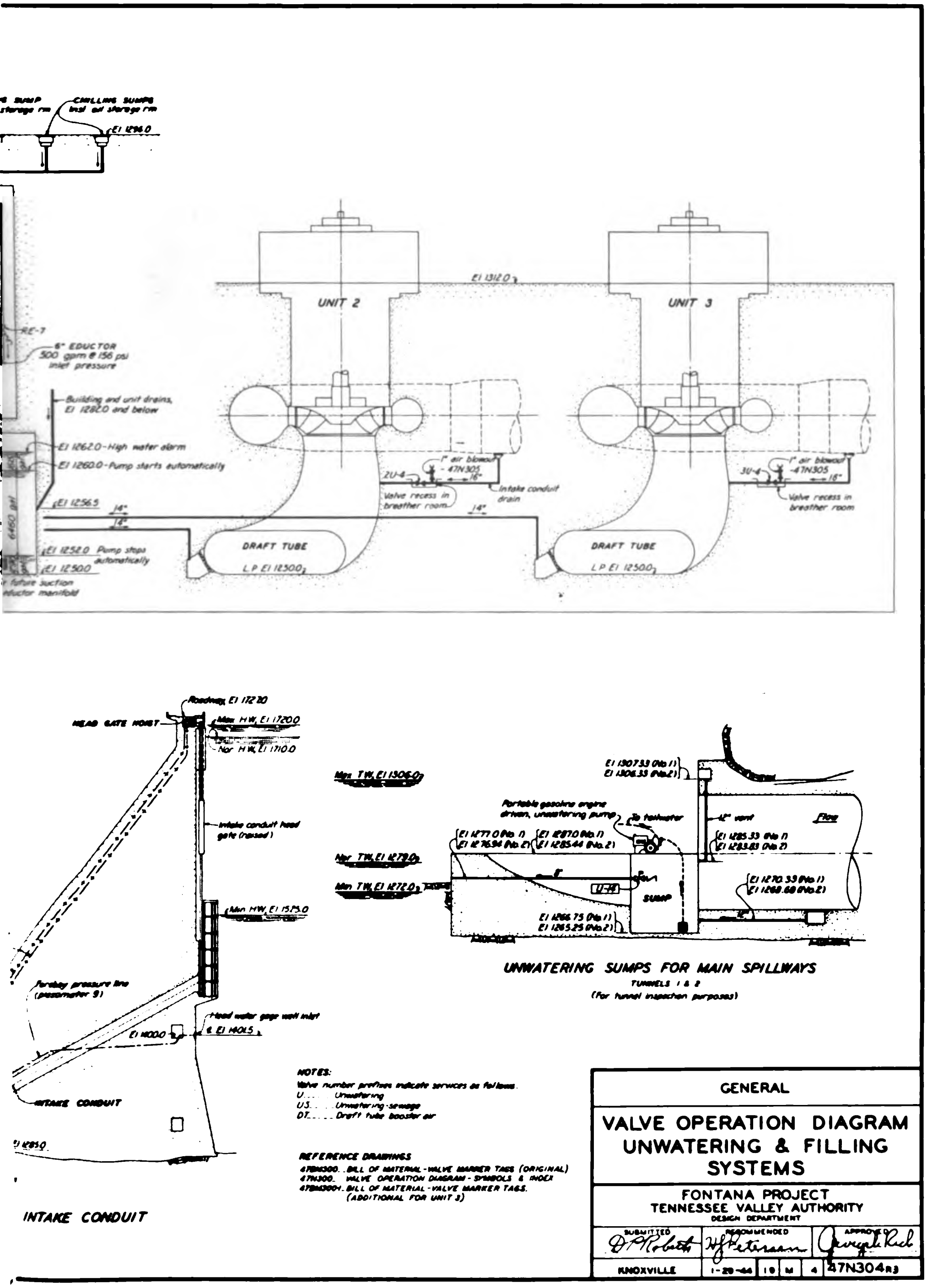
Small, portable, electric-motor-driven sump pumps are provided for pumping out electric manholes where natural drainage is not practical or for pumping out any other undrainable water around or in the powerhouse. Normally, those are used only in an emergency due to stoppages in the drainage system.

PRECAUTIONS NECESSARY DURING HIGH WATER

At some projects, during periods of high flood, special precautionary measures are necessary for the protection of certain structures and equipment. One of those is an automatic draft tube fill line provided to equalize pressure on the draft tube gates in case the draft tube is unwatered during a flood, and to prevent flotation of the structure during construction. The automatic draft tube fill line has an inlet from tailwater, usually located in a draft tube pier with a pipe extending down through the draft tube roof. Some powerhouse drainage normally discharged in tailwater is bypassed to the station sump during periods of high water.

Drainage from the spillway and intake gallery is normally carried to the station sump through a drain line, which is provided with an equalizing outlet to tailwater. If an excess amount of leakage accumulates in the gallery during high water periods, it may be necessary to allow the gallery to fill up to tailwater level by closing the valve in the drain line emptying into the station sump and allowing the excess to equalize to tailwater.


47N304
Septic influent
US-1
SEPTIC TANK
Quick opening sludge valve
US-2
El 1296.0
Septic tank effluent
Pressure water supply to eductors - 47N308
CHILLING SUMP
Oil purif room
Valve box, gas-elec generator rm
RS3-8
El 1296.0
Roof and air cond eqpt drain
Building and unit drains. Cooling water discharge from air compressor. Drain from generator air cooler vent. Drain from switchyard main leads tunnel. Battery room sink waste
Cooling water from gas-elec generator - 47N308
EDUCTOR & PUMP ROOM
El 1267.5
10" EDUCTOR
1400 gpm @ 136 psi inlet pressure
6" Flanged connection for future suction line
STATION DRAINAGE PUMP
500 gpm @ 40 ft TDH, float operated
1" blowout conn - 47N305
1" drain to sump
UNIT I
Max TW, El 1308.0
Nor TW, El 1279.0
Min TW, El 1272.0
12" EDUCTOR
2000 gpm @ 156 psi inlet press.
El 1271.0
TAILRACE
PH drain and septic effluent to TW
El 1264.0
El 1262.0
El 1267.5
Eductors and pump discharge to TW
1" air blowout - 47N305
Intake conduit drain
Valve recess in breather room
STATION SUMP
DRAFT TUBE
LP El 1250.0
Powerhouse drain and septic effluent by-pass during high tailwater
Draft tube drain and fill lines
GENERATOR LEADS GALLERIES
El 1312.0
RAW WATER & SEPTIC TANK ROOM
Influent
SEPTIC TANK
(Note: This tank to be sludged only to tailwater during normal periods, never to sump)
PIPE GALLERY
El 1296.0
Turbo-vent valve
El 1296.0
18" MANIFOLD
Well in each unit draft tube pier for possible use as suction well for portable unwatering pump
8" turbo-vent
El 1285.0
Pressure water supply to eductors - 47N308
4" air line to booster fins in draft tube
PH drain and septic discharge to tailwater
EDUCTOR ROOM
GALLERY
Septic and sludge effluent
El 1270.0
1" air blowout - 47N305
Eductor and pump discharge to tailwater
To draft tube
Draft tube drain and fill
STATION SUMP
El 1250.0
PH drain and septic effluent by-pass during high water
El 1251.5
30" pump well
Inlet on each side of intermediate pier
DIFFERENTIAL PRESSURE SWITCH
Interlocks head gate motor control so that the gate cannot be raised when the intake conduit is unwatered or an unbalanced pressure exists.
Electrical control wiring
PIPE GALLERY
El 1296.0
Max TW, El 1308.0
Nor TW, El 1279.0
Min TW, El 1272.0
Net head piezometer
(piezometer 101)
SECTION THRU POWERHOUSE
Valve numbers shown for unit 1 only
TYPICAL SECTION ON


UNIT 2
UNIT 3
DRAFT TUBE
DRAFT TUBE
6" EDUCTOR 500 gpm @ 156 psi inlet pressure
Building and unit drains, El 1282.0 and below
El 1262.0-High water alarm
El 1260.0-Pump starts automatically
El 1252.0 Pump stops automatically
Valve recess in breather room
Intake conduit drain
UNWATERING SUMPS FOR MAIN SPILLWAYS
TUNNELS 1 & 2
(For tunnel inspection purposes)
SUMP
Portable gasoline engine driven, unwatering pump
To tailwater
HEAD GATE HOIST
Intake conduit head gate (raised)
Forebay pressure line (piezometer 9)
Head water gage well inlet
INTAKE CONDUIT
INTAKE CONDUIT
NOTES:
Valve number prefixes indicate services as follows.
U... Unwatering
US... Unwatering-sewage
DT... Draft tube booster air
REFERENCE DRAWINGS
GENERAL
VALVE OPERATION DIAGRAM
UNWATERING & FILLING
SYSTEMS
FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
1-20-44
47N304R3

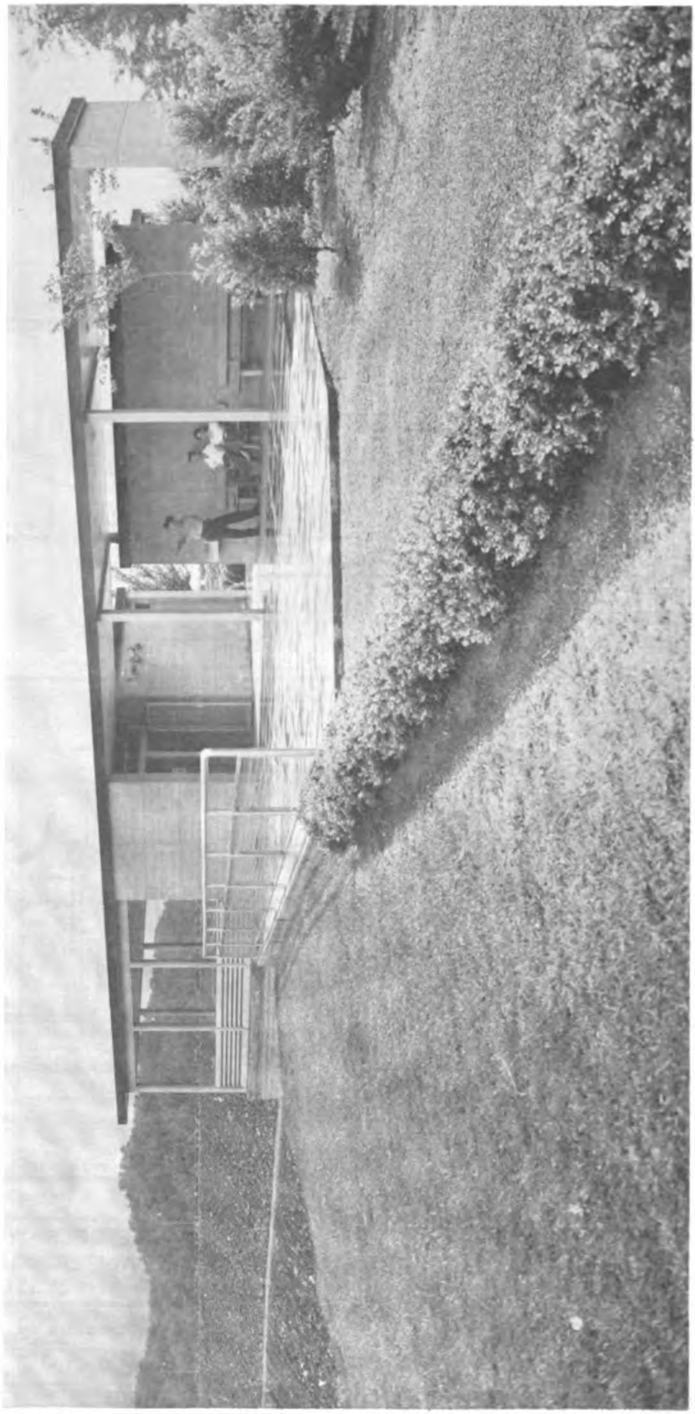


FIGURE 252.—*Visitors building above South Holston Dam*

Chapter 12

SANITARY SYSTEMS

At all hydro plants, except those remotely controlled, there are two distinct toilet accommodations—one for the use of employees and the other for the use of visitors. Toilet facilities for employees are located convenient to work areas and, in the case of large plants, two or more toilet rooms are often provided to promote more efficient plant operation. Visitors' toilets are always located adjacent to the visitors' lobby in the powerhouses or control buildings. Miscellaneous buildings located on the project reservations such as overlook buildings, maintenance centers, toilet buildings, public safety service offices, locks, picnic area shelters, water-treatment plants, and any other place where operating or service employees are stationed or where visitors may enter, are also equipped with toilet facilities. Figure 252 shows the visitors' building at South Holston Dam which contains public toilet facilities.

The principal employee toilet room in each powerhouse is located in the service bay and is combined with or adjacent to the employees' locker room. The general arrangement of these facilities is the responsibility of the architect who determines, in cooperation with the Division of Power Operations, the number of lockers and fixtures required. The number of lockers is always considerably more than the normal complement of operators in order to fill the needs of periodic visits by inspection and maintenance crews.

The number of visitors to each project varies greatly depending upon accessibility, publicity, beauty, and other tourist attractions. Estimates of the possible number of visitors to be accommodated during any one day is the responsibility of the site planning and public safety service organizations. From these estimates the sizes of both visitors' lobby and toilet facilities are determined. An estimated total of 88,997,115 visitors has been received at the TVA hydro and steam plants since the start of operations in 1933 (through the end of 1957). An estimated total of 11,495,682 visits was made to TVA installations during the year of 1957. Of this latter total, 11,273,522 visited the hydro plants and the remainder, the steam plants.

The visitors' lobby, observation gallery, and entranceways are designed especially for pleasing, comfortable appearance with easily maintained and cleaned construction materials; the visitors' toilets are in keeping. Before World War II colored toilet fixtures were used to blend into or contrast with the color scheme of the other features. During the war only white fixtures were available and these have been used exclusively since that time.

Toilet rooms in buildings other than the powerhouse, having visitors' facilities, are also made as attractive as justified and, in all cases, cleanliness is of first concern. Those toilets for employee

use only in buildings other than the powerhouse are usually of a utilitarian design with appearance secondary to cleanliness and durability.

The design of the plumbing systems in the hydro plants and miscellaneous buildings follow the "Recommended Minimum Requirements for Plumbing," which standard was later superseded by the "Uniform Plumbing Code" and the "National Plumbing Code," all of which are the work of the U.S. Department of Commerce.

PLUMBING

Toilet room fixtures

In general, siphon-jet water closets operated with flush valves are used in all the hydro plants and miscellaneous buildings. This type of closet has a large waterway which reduces maintenance to a minimum, especially in public toilet rooms. Vacuum breakers are provided on the supply to the closet to prevent polluted water from being siphoned into the waterlines. Although ordinarily the pressure in the waterlines prevents the entrance of polluted water, a partial vacuum can be generated which will allow siphonage to occur. In some of the remote control plants where sufficient water pressure is not available, tank-type water closets are installed. This type reduces the possibility of a cross connection with polluted water but is more subject to vandalism than the siphon-jet type.

Vitreous china lavatories are provided with mixing faucets in all plants where hot water is available. In some remote control plants only cold water is supplied to the fixtures. In the earlier hydro plants the lavatories in the public toilet rooms are placed 2 inches out from the wall, supported on chair carriers, with the control valves placed in the wall. In later hydro plants the more conventional-type lavatories are used, with back against the wall and control valves or mixing valves mounted on the lavatory. Figure 253 shows a typical lavatory installation in the Chickamauga powerhouse visitors' toilet room.

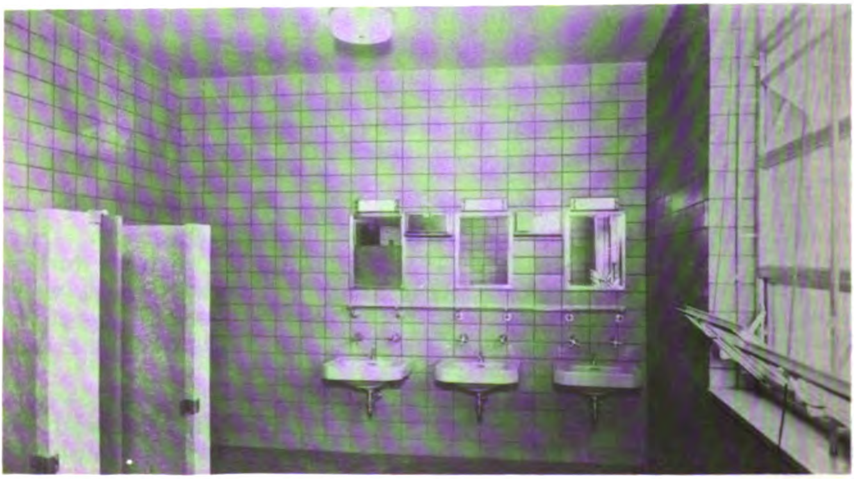


FIGURE 253.—*Visitors toilet room—Chickamauga.*

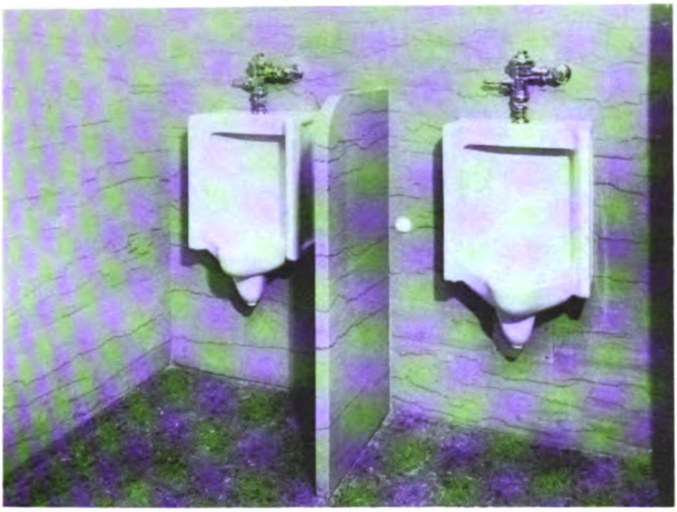


FIGURE 254.—*Typical wall-hung urinal installation.*

Wall-hung vitreous china urinals of the washout type are used. This type is more sanitary and more economical to install than the floor type. Foot valves embedded in the floor were used in the earlier plants but were discontinued in the later plants because they require considerable maintenance. Figure 254 illustrates a typical wall-hung urinal installation.

First-aid rooms

Cast-iron service sinks, enameled inside and painted outside, are used in the first-aid rooms. These sinks have hospital type supply fittings with wrist-control handles.

Miscellaneous fixtures

In the earlier hydro plants a stoneware sink was provided in the battery rooms. Due to the limited use and cost, these sinks were replaced in the later plants with acid-resisting cast-iron sinks.

Compact kitchen units which combine a kitchen sink, refrigerator, and hotplate are installed adjacent to the control rooms in the hydro plants for the convenience of the operators. One of the earlier-designed employees' kitchens is shown in figure 255.

Water coolers

Drinking water is supplied by several self-contained electric water coolers located in convenient places in the hydro plants. Fabricated wall fountains are used in the public lobbies at some of the plants. Several types of special drinking fountains have been devised to harmonize with the architecture in their particular location. These special types, shown in figures 256, 257, 258, and 259, include all stainless steel, marble, limestone, and one installed at the Norris overlook is a section of a 36-inch shot-drilled core obtained from foundation drilling for the dam. Other special types of drinking

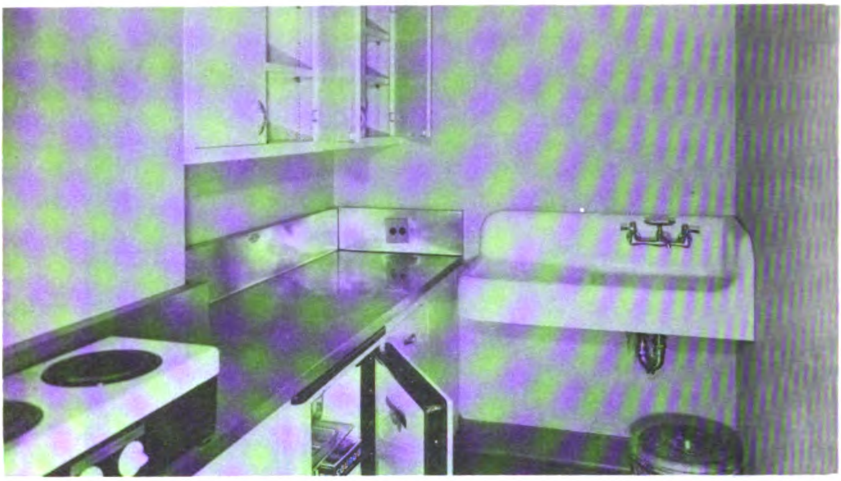


FIGURE 255.—*Employees kitchen—Chickamauga.*

fountains are sometimes constructed for public use at parking and picnic areas. Plate 33 illustrates some of these special-type fountains and their connection details. They are supplied with chilled water from small coolers located out of sight but adjacent to the fountain. In some cases, the refrigerant lines from the coolers are connected to a compressor located in another part of the building.

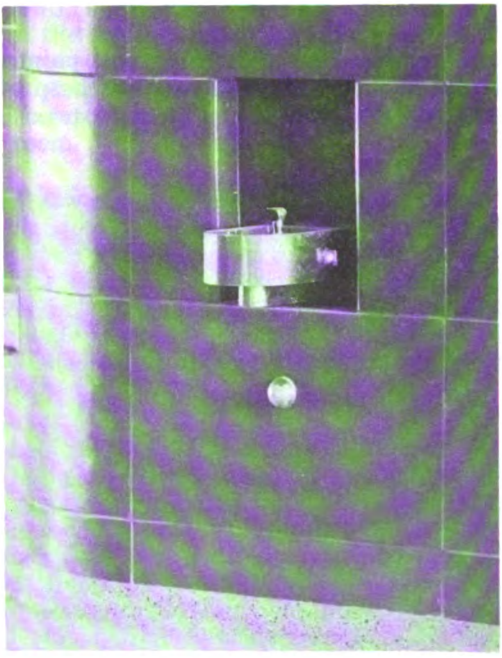


FIGURE 256.—*Special stainless-steel wall-hung drinking fountain—Wheeler.*

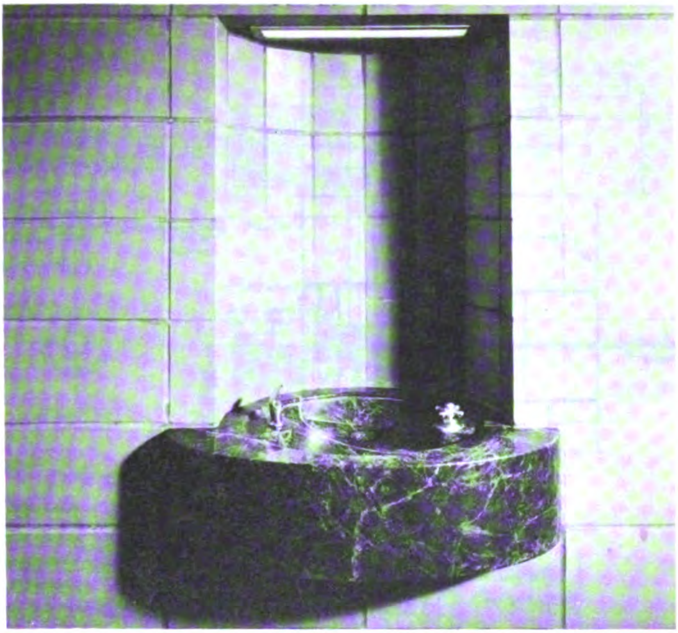


FIGURE 257.—*Marble drinking fountain—Guntersville.*

Water heaters

Hot water is supplied by automatic electric water tanks with immersion-type elements. These tanks vary in size from 10 to 120 gallons. Each tank is equipped with a thermometer and a combination temperature and pressure relief valve.

When the hot water lines are of considerable length, a small circulating pump is installed with a throttling valve located in the return line to regulate the flow. In some instances it was found more economical to purchase more than one heater, thus eliminating long runs of piping and recirculated water. A typical water heater and drinking water cooler for remote use is shown in figure 260.

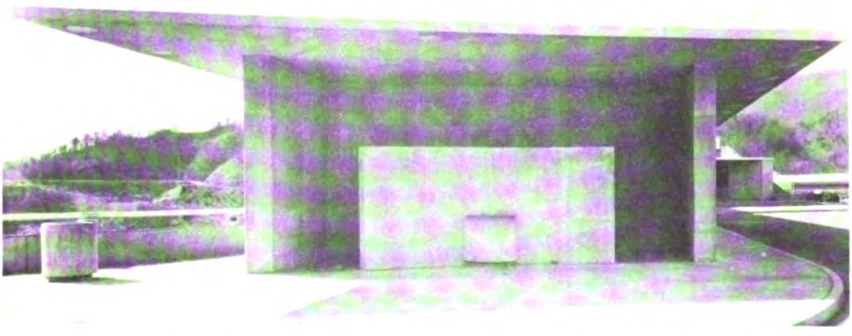
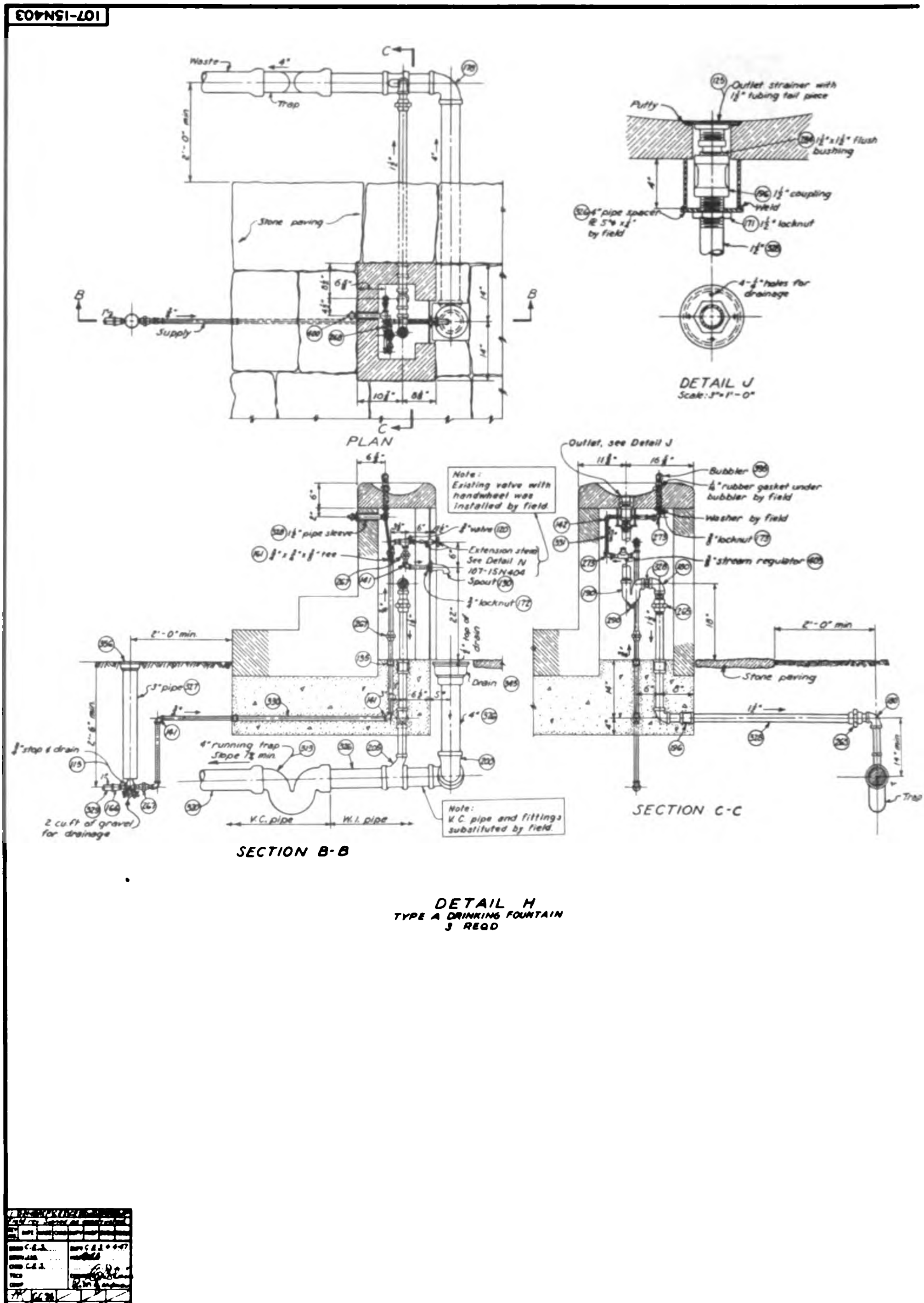
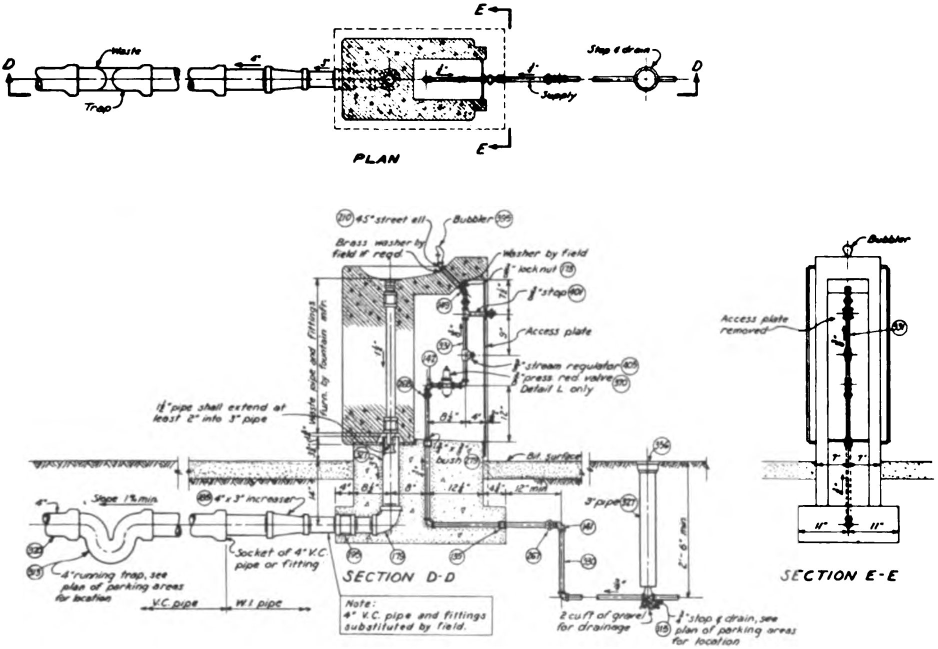


FIGURE 258.—*Limestone drinking fountains—Fontana visitors building.*



DETAIL H
TYPE A DRINKING FOUNTAIN
3 REQD



DETAIL K & L
DETAIL L AS NOTED
TYPE B DRINKING FOUNTAIN
3- REQ'D.

NOTES:
1- For exact location of type B drinking fountains see Arch dwg 106-15K300.
2- Exact location of type A drinking fountains to be determined by field forces of Regional Studies Dept.
3- For masonry details of type A drinking fountains see Arch Std dwg 30K721.
4- For masonry details of type B drinking fountains see Arch Std dwg 30K722
5- For complete list of notes and reference drawings see dwg 107-15N400.

NOT TO SCALE

Scale 1"=1'-0"
Except as noted

SITE IMPROVEMENT
RIGHT & LEFT BANK

MECHANICAL
PARKING & PICNIC AREAS
WATER LINES-SHEET 4

CHEROKEE PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

RECOMMENDED	REVIEWED	APPROVED
		R.A. Monroe
KNOXVILLE	4-4-47	12 M 8 107-15N403 R1

REGIONAL STUDIES DEPARTMENT
By Geo. L. Richardson 4-10-47

THIS DRAWING SUPERSEDES DWGS 17W200 AND 201
COMPANION DRAWINGS 107-15N400, 401, 402 AND 404

FIGURE 259.—*Drinking fountain at Norris Dam overlook—made from 36-inch core from foundation drilling for dam.*

Piping

All exposed soil and waste lines are standard galvanized wrought-iron pipe with black, screwed drainage fittings. Extra-heavy, cast-iron soil pipe and fittings are used for embedded lines. Originally TVA installed floor drains in the toilet rooms to aid in washing the floor. These have been eliminated in the later hydro plants because the infrequent use of these drains caused the water in the trap to evaporate. Unless an effort is made to keep these traps filled with water, sewer gas will enter the room. Floor drains with caulked outlets are used, which permit the drain to be set level with the floor if the waste pipe is out of plumb. Sanitary drains within buildings are laid to grades of either 1/8 or 1/4 inch per foot depending upon the headroom and space available and the required clearance of these waste lines with other piping and equipment.

Galvanized wrought-iron pipe with galvanized malleable-iron fittings are used for the vent lines. If possible, all vents are connected to the main stack. This eliminates an unsightly appearance of

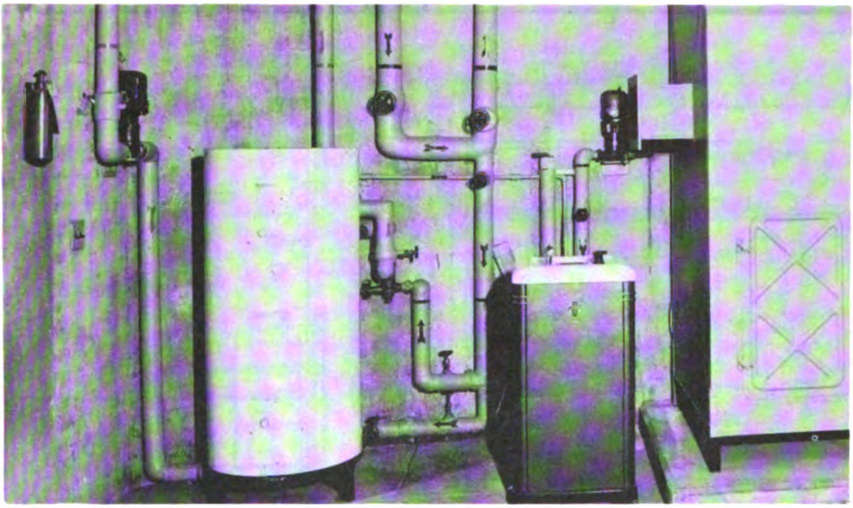


Figure 260.—*Electric water heater and drinking water cooler—Fort Loudoun lock.*

several pipes projecting through the roof. In a few instances antisiphon traps have been used when the construction of the building prevented the installation of vents. Properly designed antisiphon traps resist back pressure somewhat more than unvented plain traps of the same depth of seal, but the difference is not sufficient to justify their general use without vents.

In the earlier hydro plants copper tubing and solder-joint fittings were used for the waterlines. During World War II and later, copper tubing was not available and on plants built during this time galvanized wrought-iron pipe and galvanized malleable-iron fittings were used.

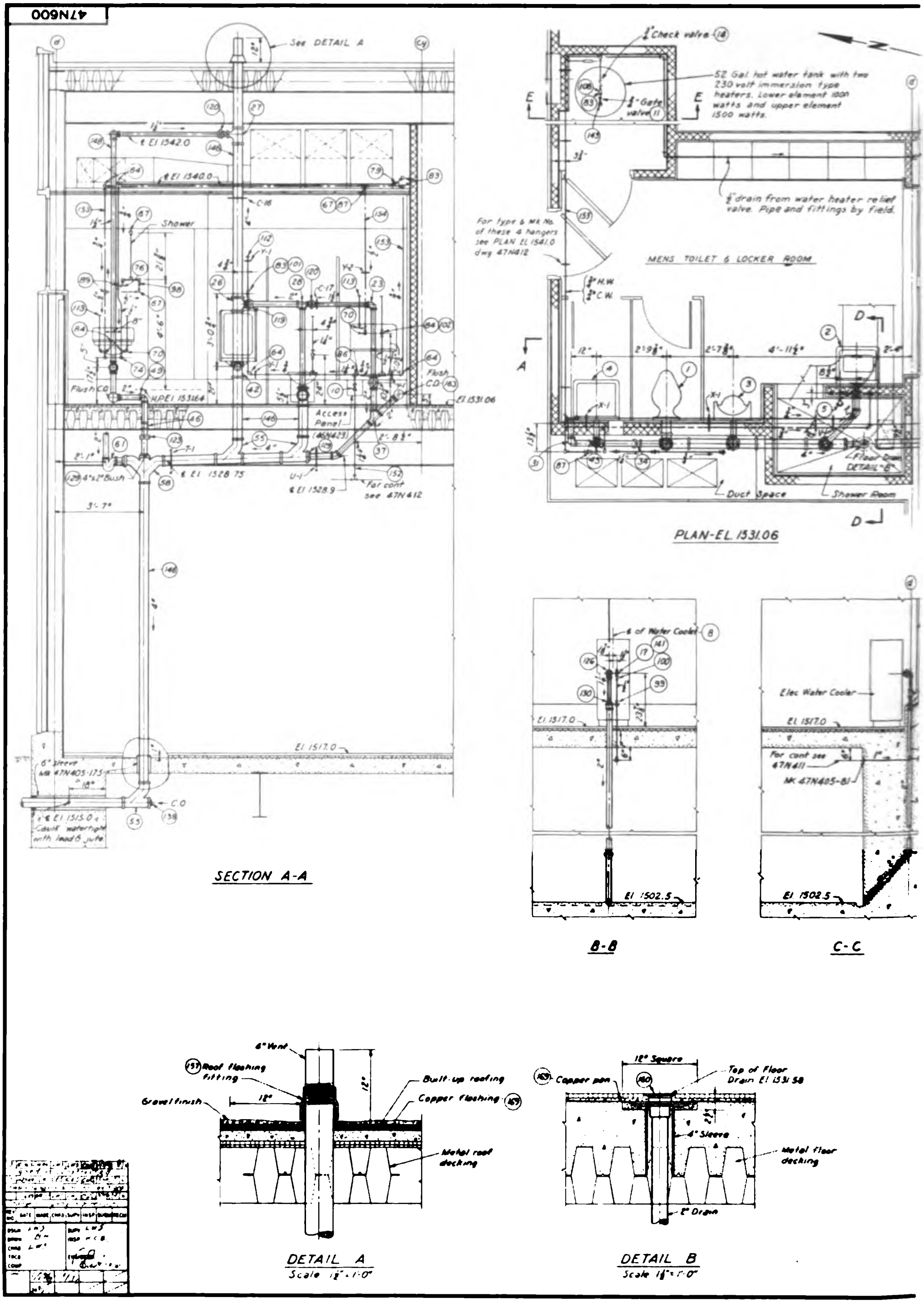
Valves or stops are provided at each fixture which permit the removal of faucet washers without shutting off a whole group of fixtures. Air chambers 18 inches long are installed as close to the fixtures as possible to absorb the pulsations of pressure above and below normal caused by quick-closing faucets or valves.

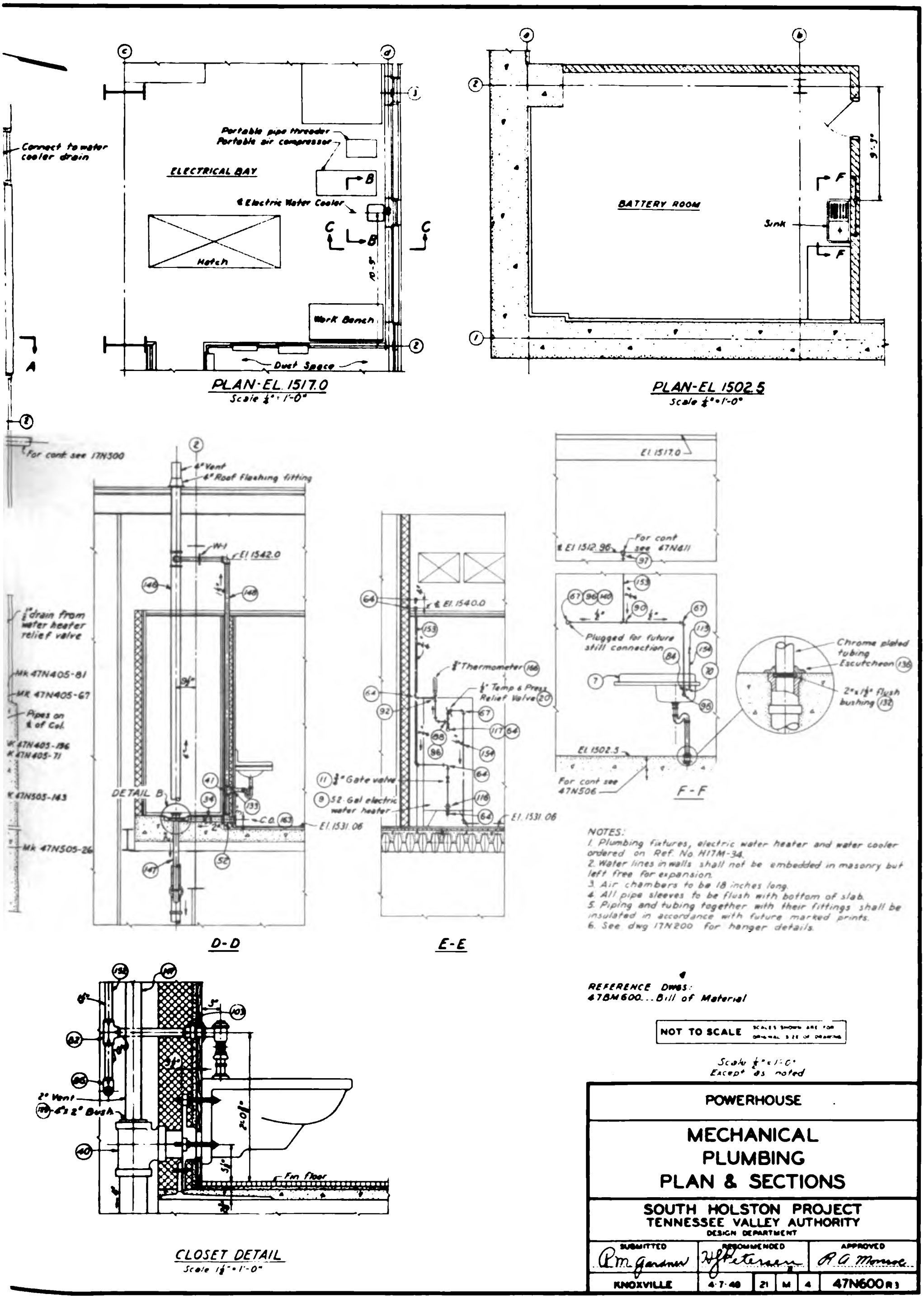
Plate 34 illustrates a typical powerhouse plumbing design drawing from which the actual installation is constructed. Plate 35 is a similar design drawing of the isometric type prepared for a construction camp building.

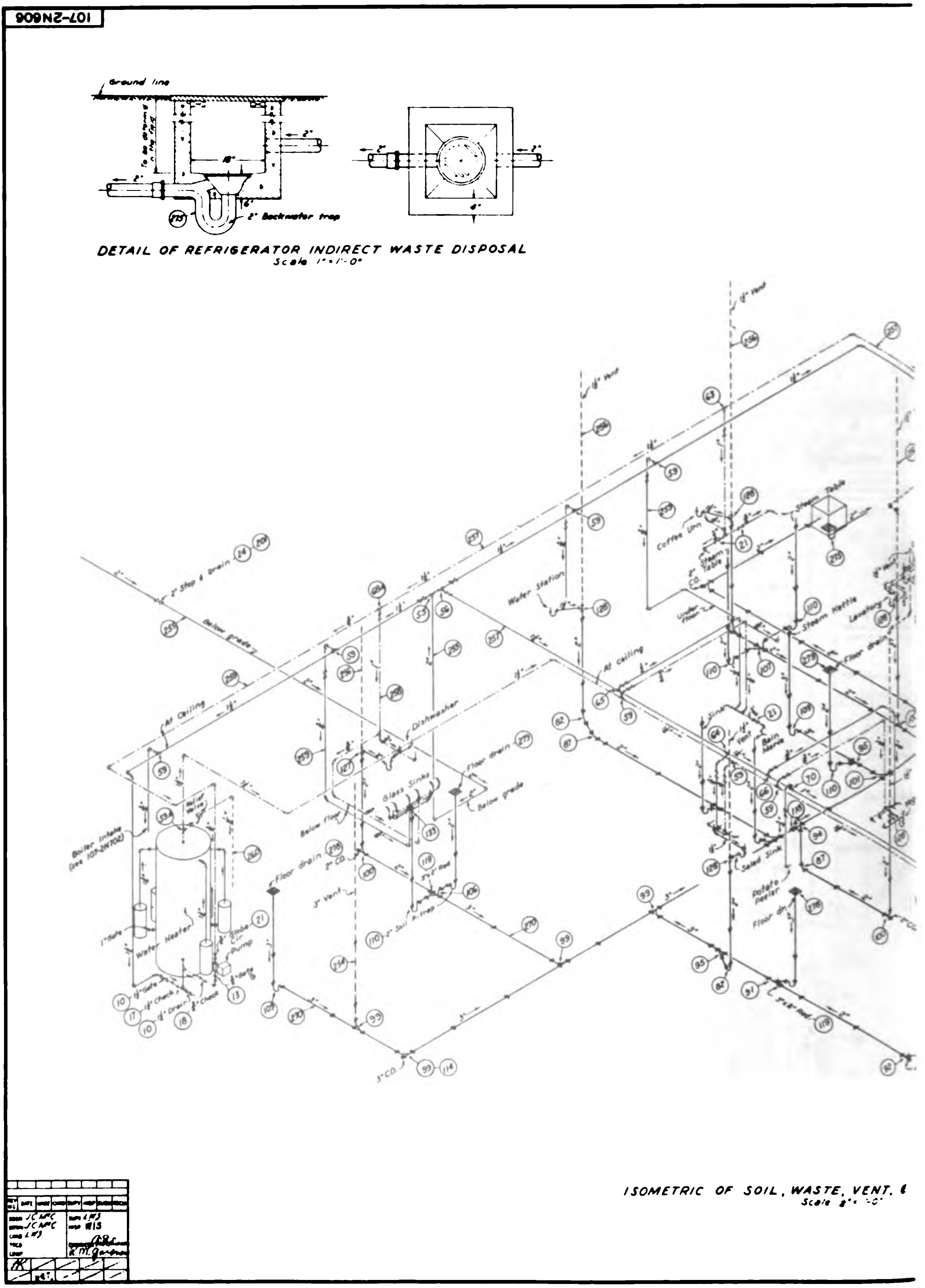
SEWERAGE

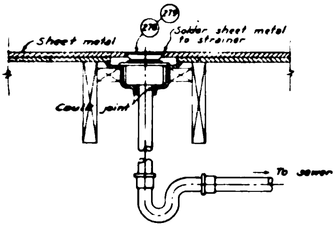
Health department requirements

The design drawings for the sewerage systems of the hydro plants and miscellaneous buildings are submitted to the appropriate state health department for approval through the TVA Division of Health and Safety. Although TVA is not legally bound to do this, it is done as a matter of policy. The TVA Division of Health and Safety makes periodic checks of the septic tanks and arranges for sludge removal when necessary.

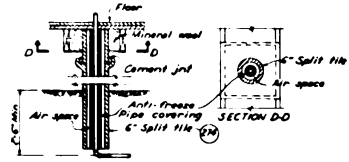

47N600
See DETAIL A
Shower
Flush C.O.
Access Panel
For cont see 47N412
SECTION A-A
6" sleeve Mk 47N405-175
Caulk watertight with lead & jute
52 Gal hot water tank with two 230 volt immersion type heaters. Lower element 1000 watts and upper element 1500 watts.
Check valve
Gate valve
drain from water heater relief valve. Pipe and fittings by field.
For type & Mk No. of these 4 hangers see PLAN EL 1541.0 dwg 47N412
MENS TOILET & LOCKER ROOM
H.W.
C.W.
Floor Drain DETAIL B
Duct Space
Shower Room
PLAN-EL. 1531.06
of Water Cooler
Elec Water Cooler
For cont see 47N411
MK 47N405-81
B-B
C-C
6" Vent
Roof flashing fitting
Built-up roofing
Copper flashing
Gravel finish
Metal roof decking
DETAIL A
12" Square
Copper pan
Top of Floor Drain El 1531.58
4" Sleeve
Metal floor decking
2" Drain
DETAIL B


Connect to water cooler drain
Portable pipe threader
Portable air compressor
ELECTRICAL BAY
Electric Water Cooler
Hatch
Work Bench
Duct Space
PLAN-EL 1517.0
Scale ¼"=1'-0"
BATTERY ROOM
Sink
PLAN-EL 1502.5
Scale ¼"=1'-0"
For cont see 17N500
6" Vent
6" Roof Flashing fitting
El 1542.0
½" drain from water heater relief valve
Mk 47N405-81
Mk 47N405-67
Pipes on ℄ of Col.
DETAIL B
El 1531.06
El 1540.0
¾" Thermometer
¾" Temp & Press Relief Valve
¾" Gate valve
52 Gal electric water heater
El 1517.0
El 1512.96
For cont see 47N611
Plugged for future still connection
El 1502.5
For cont see 47N506
Chrome plated tubing
Escutcheon
2"x1½" Flush bushing
D-D
E-E
F-F
NOTES:
1. Plumbing fixtures, electric water heater and water cooler ordered on Ref. No H17M-34.
2. Water lines in walls shall not be embedded in masonry but left free for expansion.
3. Air chambers to be 18 inches long.
4. All pipe sleeves to be flush with bottom of slab.
5. Piping and tubing together with their fittings shall be insulated in accordance with future marked prints.
6. See dwg 17N200 for hanger details.
REFERENCE DWGS:
47BM600...Bill of Material
NOT TO SCALE
Scale ¼"=1'-0" Except as noted
2" Vent
Fin floor
CLOSET DETAIL
Scale 1½"=1'-0"
POWERHOUSE
MECHANICAL
PLUMBING
PLAN & SECTIONS
SOUTH HOLSTON PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
4-7-48
47N600

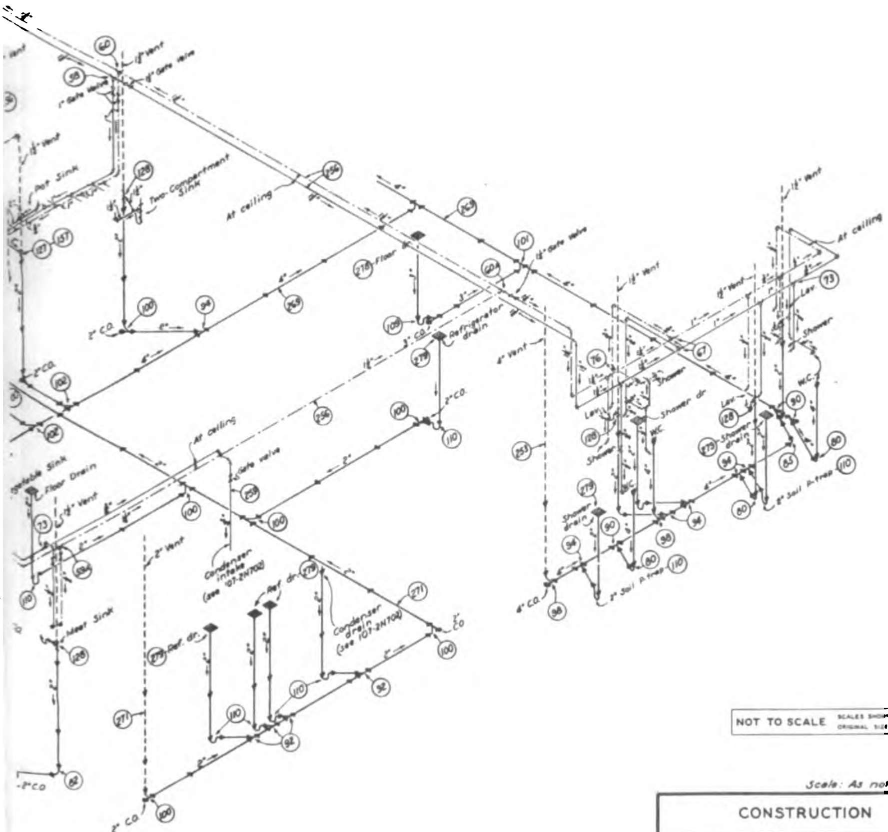

107-2N606
Ground line
2" Backwater trap
DETAIL OF REFRIGERATOR INDIRECT WASTE DISPOSAL
Scale 1" = 1'-0"
Coffee Urn
Steam Table
Water Station
Dishwasher
Glass Sinks
Floor drain
Below grade
Below floor
Water Heater
Boiler intake (see 107-2N702)
At ceiling
Below grade
2" Stop & Drain
Steam Kettle
Lavatory
Floor drain
Sink
Bain Marie
Salad Sink
Potato Peeler
Floor dr.
ISOMETRIC OF SOIL, WASTE, VENT, &



DETAIL OF FLOOR DRAINS
Scale 1½"=1'-0"



EXPOSED WATER PIPE INSULATION
No Scale



NOT TO SCALE — SCALES SHOWN ARE FOR ORIGINAL SIZE OF DRAWING

Scale: As noted

CONSTRUCTION CAMP
MECHANICAL MESS HALL PLUMBING-SHEET 2
WATAUGA PROJECT TENNESSEE VALLEY AUTHORITY DESIGN DEPARTMENT

RECOMMENDED	REVIEWED	APPROVED
H. J. Petersen	H. B. Allen	R. A. Monroe
KNOXVILLE	10-1-46 22 M 8	107-2N606R

WATER PIPING

Companion dwg 107-2N605

PLATE 35

Sewers

The sanitary sewer system connects with the individual building sewers at a point about 5 feet outside the building wall. In general, the yard sewers are either vitrified clay or concrete and an adapter is necessary to connect with the usual cast-iron soil pipe building sewers. Yard sewers are 6-inch minimum size and usually the adapter is also in the form of an increaser because usually the building drains are 4-inch size. Usually the toilets are on the ground floor and the sewers consequently leave the buildings with only 2 or 3 feet of cover.

Manholes are installed on the yard sewer lines at every change in grade or alignment and at a maximum spacing of 250 feet. Where the sewer is at least 4 feet deep these manholes are the usual standard brick type, 4 feet in diameter at the bottom and tapering in at the top to fit a cast-iron manhole frame and cover with a 21-inch-diameter opening. The purpose of the manholes is for inspection and cleaning of the sewers and they are equipped with cast-iron manhole steps for ease of access. On shallow sewers this type of manhole is impractical and a rectangular one is substituted. This is 4 feet in length but narrow and fitted with a rectangular cast-iron frame and cover. The length permits the use of standard sewer rods and the narrow width allows a reasonable weight cover to be used.

Minimum grades are established to produce at least 2-foot-per-second velocity when the sewer is running half full. These grades are as follows:

Pipe size—inches:	*Percent grade*
6	0.50
8	.35
10	.27
12	.22

The velocity produced by these grades prevents a deposition of solids in the sewers. A grade producing a velocity greater than 8 feet per second causes scour and a rapid wear of the sewer. This condition is eliminated either by the use of cast-iron pipe which will resist the wear better or by the use of drop manholes. The upper right of plate 36 illustrates TVA standard manhole details.

Primary sewage treatment

The quantity of sewage from any of the hydro plants or related facilities is so small that the only practical acceptable method of treatment is by septic tanks or Imhoff tanks. In sizing the septic tanks a minimum detention period of 24 hours is provided. The volume on which this is based is the sum of a flow of 25 gallons per day per employee for the average number of employees plus the maximum continuous use for 8 hours of all toilet fixtures provided for visitors' use. In places where many visitors can be accommodated the tanks are up to 5,700 gallons in capacity. At installations where only a few employees are stationed, the minimum sized tank approved by the involved State is more than adequate. The effluent from most of the tanks located within powerhouses flows di-

rectly to tailwater. Most of the others have some form of secondary treatment.

The majority of the septic tanks within powerhouses are of steel construction. Figure 261 shows the tank serving the Chickamauga powerhouse. They are usually constructed of $\frac{3}{8}$-inch steel and located in the service bay. Many of the older plants had provision for emptying sludge to tailwater during periods of high flow in the river. This was before requirements against stream pollution were tightened and it was assumed that the high river flow would provide enough dilution to make the sludge unobjectionable. None of the newer plants has this feature and the valves and piping for this sequence have even been removed on some of the old plants to prevent their use. In these cases sludge removal is difficult, requiring drawoff into barrels and removal by truck.

Wherever possible septic tanks are made of concrete and located outside of the structure served. This makes for easier cleaning and addition of any future secondary treatment facilities. All tanks have vented inlets and outlets, either in the form of pipe tees or baffles. At least one manhole is provided for sludge removal and floor boxes are installed over each inlet and outlet as inspection ports. The tank effluent flows by gravity to either some form of secondary treatment or to tailwater. In some of the powerhouses the effluent must be diverted to the station sump during periods of high tailwater because this level is higher than the tank and backflow would occur. The necessary piping and valves are always provided wherever this might occur.

Many manufacturers of cast-stone products make precast concrete septic tanks conforming to the minimum size approved by the health department of the State in which they are located. This varies from 540 to 600 gallons. TVA uses these tanks wherever possible because the cost is appreciably less than a cast-in-place tank. Figure 262 illustrates a tank of precast type installed at the Nottely project.

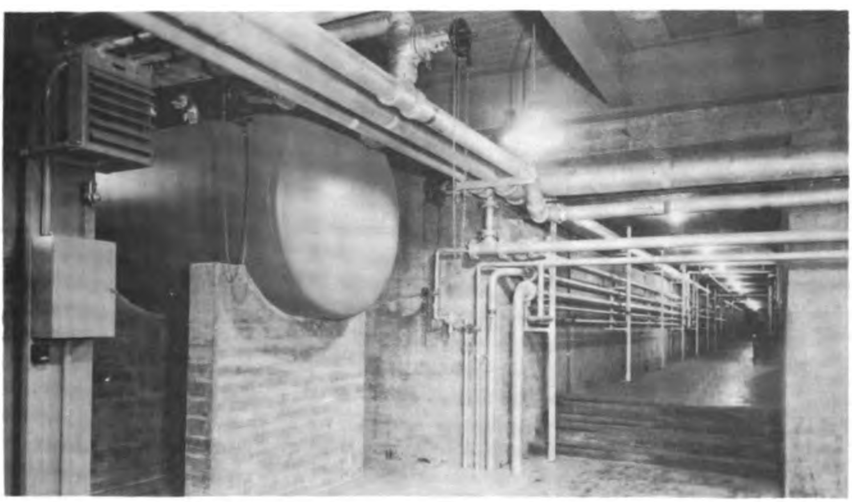
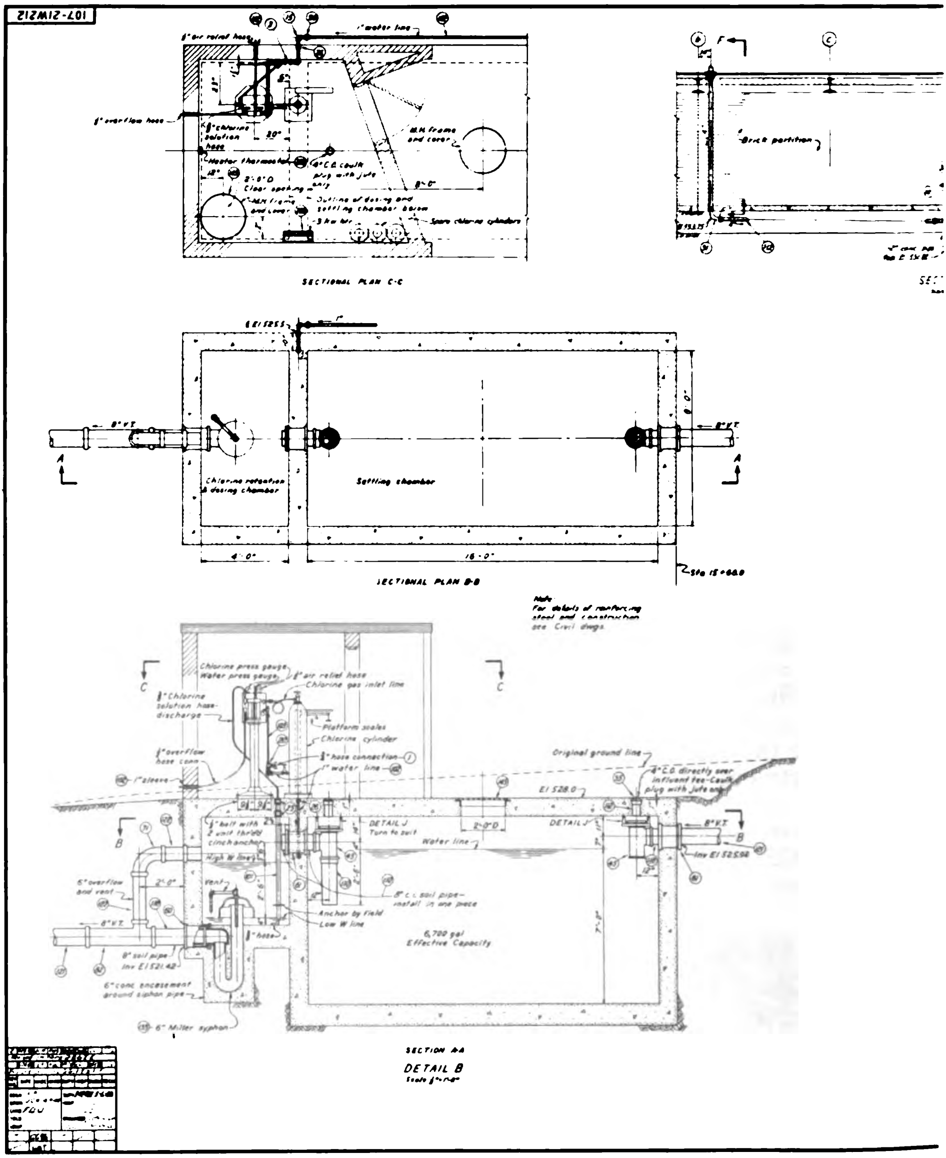


FIGURE 261.—*Steel septic tank in Chickamauga powerhouse.*


SECTIONAL PLAN C-C
SECTIONAL PLAN B-B
Chlorine retention & dosing chamber
Settling chamber
Brick partition
Note: For details of reinforcing steel and construction see Civil dwgs.
Chlorine press gauge
Water press gauge
Chlorine gas inlet line
Platform scales
Chlorine cylinder
Original ground line
Water line
High W line
Low W line
6,700 gal Effective Capacity
6" Miller syphon
6" overflow and vent
SECTION A-A
DETAIL B

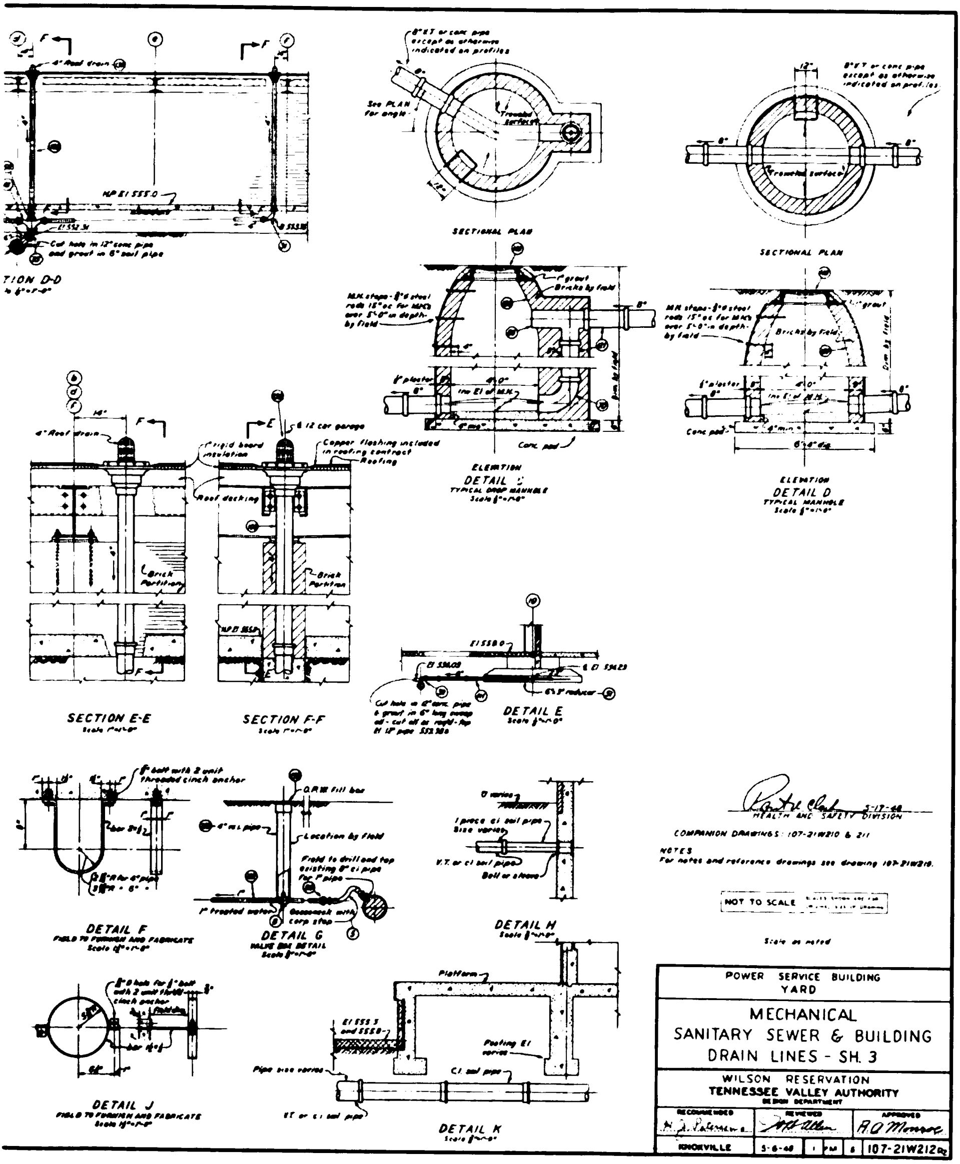

SECTIONAL PLAN
ELEVATION
DETAIL D
TYPICAL MANHOLE
SECTION E-E
SECTION F-F
DETAIL E
DETAIL F
DETAIL G
VALVE BOX DETAIL
DETAIL H
DETAIL J
DETAIL K
NOT TO SCALE
POWER SERVICE BUILDING
YARD
MECHANICAL
SANITARY SEWER & BUILDING
DRAIN LINES - SH. 3
WILSON RESERVATION
TENNESSEE VALLEY AUTHORITY
KNOXVILLE
107-21W212

PLATE 36

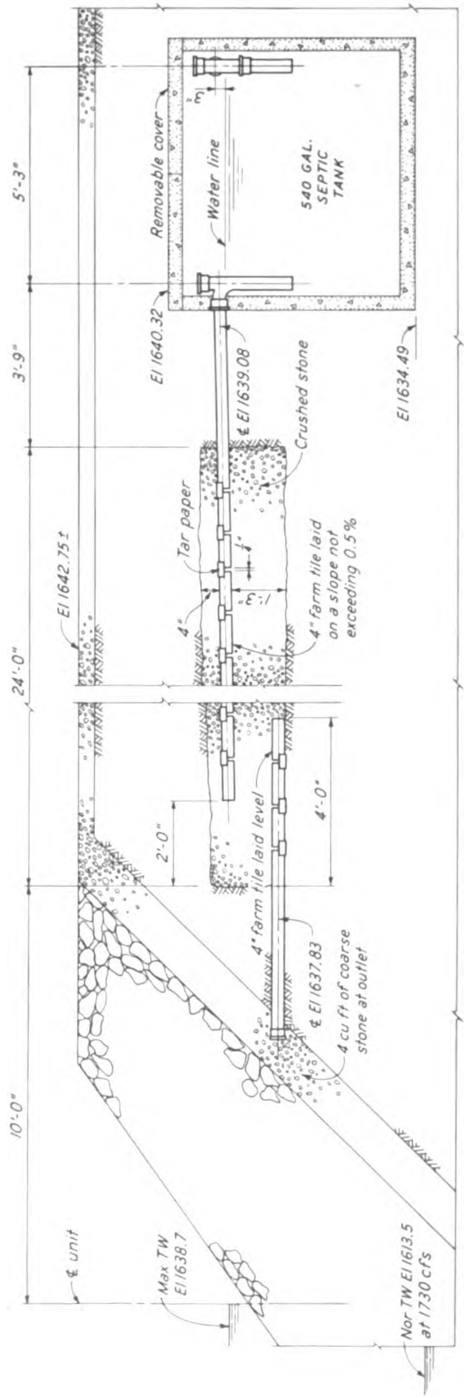


Figure 262.—*Precast septic tank and disposal field—Nottely.*

Most of the sewage from the Wilson and Wheeler Dam Reservations and all from the Fontana Village are treated in Imhoff tanks. The plant at Wilson has been in continuous service since 1918. The one at Fontana was designed and built after completion of the dam and powerhouse and it was decided to keep the construction village as a resort, leased to a private organization. Originally the village sewage flowed untreated to the river but with use of the stream for recreational purposes sewage treatment was necessary. Plates 2, 3, and 4, pages 194, 196, and 198, show the design drawings for this plant and figure 263 is a photograph of the completed structure.

The Fontana plant operates on gravity flow throughout all functions. It consists of coarse rocks, a 2-story tank, and sludge-drying beds. The upper story of the tank acts as a settling tank and the lower story serves as a sludge digestion tank. The settling tanks provide a 2-hour retention based upon a design capacity of 150,000 gallons per day of sewage flow. The digestion chamber has a capacity of 3,000 cubic feet based upon 2 cubic feet per estimated 1,200 persons living in the village plus an allowance for transient use. The sludge-drying beds have 1,500 square feet of net area based upon 1 square foot for the same population.

Secondary treatment

The only practical methods for secondary treatment of the small flows of primary effluent at TVA installations is by either subsurface soil absorption or chlorination. On practically all of the small septic tank installations the former method is used. If there is any doubt of the ability of the soil to absorb the anticipated flow percolation tests of the soil are made and the area of the tile field sized accordingly. Instead of having individual trenches for each line of distributing tile, it has been TVA practice to exacavate a trench with an area equal to that required for absorption. The whole area is filled with crushed rock or gravel and the tiles laid at 8-foot centers, covered with rock and filled to grade with the excavated material.

In a few instances where the septic tank is located adjacent to a riprapped fill, a perforated pipe of suitable length is laid below the surface adjacent to the riprap. The septic tank effluent is discharged into this pipe which distributes it under the riprap where it percolates downward in a well-aerated state, simulating a trickling filter. The largest unit of this type is for the Fontana visitors' building where maximum flows of 5,700 gallons per day are anticipated. A similar installation of this type is shown in figure 262.

At a few septic tank installations where the soil is impervious, making a tile field impractical but where secondary treatment is necessary, an underground underdrained filter is used. These are constructed similar to the ordinary tile field described above except considerably deeper and much finer stone is used and the whole area underdrained. The effluent is carried to the nearest water course.

Some of the larger septic tanks having tile fields for absorption of the effluent are built with dosing chambers. This chamber is equipped with an automatic siphon which releases the effluent only when the chamber is full. The volume released is about three-fourths the volume capacity of the distributing pipes in the tile field. This feature ensures the complete utilization of the field and not

the small portion near the inlet which might be the case with low flows.

In instances where other methods for providing required secondary treatment are too costly, chlorination of the effluent is used. To be effective some retention of the effluent in contact with the chlorine is desirable. At the Wilson Imhoff tank installation, a chlorine contact tank provides 30-minute retention before discharge to the reservoir. The installation for the Power Service Building is shown at the left on plate 36, page 544. Here a dosing chamber serves the dual purpose of a chlorine contact tank and a means of flushing out the long outfall sewer line. Both of these installations are provided with manually controlled gas chlorinators feeding chlorine in solution.

At some of the older hydro plants, where septic tank effluent originally flowed without further treatment to tailwater, recent stream pollution standards require further treatment. This has been accomplished by feeding a hypochlorite solution into the effluent.

Outfall sewers

All outfall sewers, whether carrying raw or treated sewage, discharge into the nearest main stream below minimum tailwater. The outlet is protected against damage by a concrete headwall and usually the pipe itself is changed to cast iron or steel for the last few feet to provide better insurance against breakage. Some outfalls are placed below minimum water in order to comply with local state health department requirements. The latest designs, wherever possible, carry the outfall above normal water level so that the sewers will be ventilated most of the time. This prevents the accumulation of explosive gases which endanger life and property and the accumulation of hydrogen sulfide gas which is so destructive to concrete sewers.

FIGURE 263.—*Sewage treatment plant—Fontana Village.*

Chapter 13

FIRE PROTECTION

Careful consideration has been given the problem of fire protection in the design of TVA's hydroelectric power stations. Prior to construction, plans of camps, villages, and other projects are reviewed, and plans for fire-protection and alarm systems are coordinated between the Divisions of Design, Power Operations, Construction, and Health and Safety. Wherever practicable, National Fire Protection Association standards and codes are adopted as the minimum good practice.

Fires occurring in power generating stations and switchyards usually involve, besides the actual cost of repairing or replacing damaged equipment, a direct loss in operating revenue and loss of customer's good-will in event of power failure. However, the first objective of all fire protection is the prevention of loss of life or personal injury.

This chapter describes, in general, the steps which have been taken toward the control of fire hazards and the development of various fire-protection systems.

MINIMIZATION OF FIRE OCCURRENCE

TVA's hydroelectric power plants and auxiliary structures, such as control buildings and oil purification buildings, are of fire-resisting construction. Building substructure walls and floors are concrete. Superstructure walls and partitions are concrete, brick, tile, limestone, or metal construction. Floors usually have concrete structural slab bases and finishes, with public and office areas having tile or terrazzo finishes. Roofs generally are double-layer precast concrete slabs supported by steel beams. Roofing materials are placed over the bottom slab and an air space is provided between the roofing and the precast slab which forms the walking or wearing surface. Windows usually have metal sash. Doors are of hollow-metal construction and ventilation louvers are generally of steel or aluminum. Steel roof and floor beams and columns in hazardous locations are protected by an encasement of concrete or brickwork.

Indoor switchgear, transformers, and other pieces of electrical equipment are either segregated into compartments with asbestos, concrete, or metal housings, or are suitably spaced so that a fire in one unit will not be readily communicated to another. Bus bars and cables are similarly separated and protected by fire-resisting partitions or trays. Floors of oil-filled transformer and switchgear cubicles are provided with curbs and individually trapped drains to rapidly drain away any spilled oil.

Rooms housing oil storage and purification facilities are always separated from other parts of the building by fireproof partitions

FIGURE 264.—*Self-closing metal fire door of room housing gasoline-driven generator—part of CO_2 fire protection system on wall at left—Chickamauga.*

of brick or concrete construction having a minimum thickness of 9 inches. Each door opening is fitted with a self-closing metal fire door (fig. 264) on the inside of the room which is held open on a sloping track by a counterweight with a fusible link. These doors are also provided with pressure trips which close them in case the carbon-dioxide fire-extinguishing system is operated. Each doorway is also fitted with a hinged emergency door which opens outward from the room. Large drains are provided, with generous slopes in the floor to the drains in case of oil spillage. Concrete curbs having a minimum height of 4 inches are built under each partition and across the doorways to confine the spread of oil. Ventilation openings in oil rooms are fitted with dampers having pressure trips for closing, similar to those furnished for the fire doors. Openings and sleeves for pipes entering the room are calked with mineral wool or closed with a steel cover plate. Vaporproof light globes are usually provided in oil and battery rooms.

Gasoline-engine-driven generators are always installed in separate rooms (fig. 264), constructed in a manner similar to the oil rooms. Gasoline supply tanks for such units are buried in the fill outside the powerhouse, and no suspended auxiliary tanks within the room are permitted.

Switchyard and other outdoor electrical equipment, such as transformers, oil circuit breakers, reactors, and metering equipment, are all very carefully spaced in accordance with accepted standards and provided with lightning arresters. Gravel fill is placed throughout all switchyards with sloping underbeds wherever possible, to facilitate the rapid draining of any spilled oil to some point away from the equipment. Where this is not possible, pipe underdrains or trenches are placed beneath the surface gravel to localize fire zones. Where transformers and oil circuit breakers are located on roofs or decks of the powerhouse, they are either suitably spaced or provided with sectionalizing concrete fire walls. Large curbed drain sumps are installed beneath each unit. Sumps are drained either to the forebay or tailrace, depending on which is the most convenient. Individual sump drains are not interconnected so that a fire in one piece of equipment cannot ignite another unit by flashing through the drainage system.

CLASSES OF FIRES AND EXTINGUISHING AGENTS

The three generally understood classes of fires are set forth below, in order that the selection of various fire-extinguishing agents may be explained.

Class A.—Fires in this class are those in ordinary combustible materials such as wood, paper, and rubbish. The use of water or solutions containing large percentages of water, which produce a quenching and cooling effect, is recommended. In addition to application of water from hose lines, effective extinguishment may be obtained by use of water-solution-type, hand-operated extinguishers such as soda-acid, plain water charged with carbon dioxide, and the loaded stream unit which contains an alkali metal salts solution.

Class B.—Fires in this class are those in flammable liquids such as oils, grease, paints, and gasoline. In such fires it is necessary to exclude the oxygen element by smothering or blanketing. For indoor hazards the use of a fixed-type carbon-dioxide system, preferably of the total flooding kind, is recommended. For outdoor fires of this class, the use of high-pressure water applied from either fixed or hose nozzles of the fog type is recommended. Direct application of portable extinguishers, such as carbon tetrachloride, carbon dioxide, foam, dry chemical, or loaded stream, is also effective.

Class C.—Fires in this class are those involving electrical equipment where a nonconducting extinguishing agent is of first importance, such as transformers, oil circuit breakers, generators, switchgear, motors, etc. Electrical fires are generally caused by arcing due to poor contacts in switches, faulty insulation, short-circuiting, ignition of gas, overheating, lightning, and the opening of switches carrying excessive amounts of power.

The possibility exists that an extinguishing agent may be applied to live equipment, and it is, therefore, necessary to use a nonconducting extinguishing agent to eliminate the shock hazard. For indoor fires of this class, the use of fixed carbon-dioxide extinguishing equipment is first recommended, and where rotating electrical machinery is involved, such as generators, provision for an extended discharge to maintain the smothering effect for a sufficient length of time to cool the equipment is made. Outdoor hazards are usually protected by portable or fixed water systems employing fog nozzles. Dry compound, carbon tetrachloride, or carbon-dioxide portable equipment are all effective, if properly used.

TRAINING OF PERSONNEL

The employees and others responsible for protection from fire of the TVA power properties are trained with respect to the cause, prevention, control, and extinguishment of fires. This training is the joint responsibility of the divisions of Power Operations and Reservoir Properties. The Division of Health and Safety also cooperates in the establishment of regular training programs and procedures. Such training consists of practice drills on fires of waste materials such as old motor oil, discarded tires, and scrap lumber; demonstrations; and lectures and meetings of employees to discuss fire prevention, first protection, and detecting and reporting procedures. Two fire-protection manuals which have been prepared by the TVA are issued to each employee responsible for the protection of power property.

Four times each year the major power properties are inspected by units of the TVA Public Safety Service in cooperation with representatives of the Division of Power Operations. Employees are instructed to develop their powers of observation for fire hazards in the performance of their regular duties. Good housekeeping is stressed, and observation of the condition of fire-protection equipment is made a part of each employee's routine duties. Posters,

movies, and bulletins are used to make each employee conscious of fire hazards.

TYPICAL FIRE-PROTECTION SYSTEMS

Improvements in the designs of later hydroelectric plants and alterations to existing fire-protection systems have been possible as dictated by experiences gained by actual operation of the earlier projects. Certain features of the individual fire-protection systems have now been standardized and are described in this section.

BUILDING PROTECTION

Water systems

Water for fire protection may be supplied from either the treated or raw water system, depending on which proves more satisfactory from the standpoint of pressure and quantity available and economy. A minimum pressure of 40 pounds per square inch at the nozzle must be available under all conditions of usage. The raw water system is generally used where it can assure this minimum pressure at all fire outlets throughout the powerhouse and switchyard. This is usually the case at the high head projects where minimum reservoir levels are sufficiently high to produce the required water pressure in the system. At the low head projects where sufficient pressure is not available from the reservoir level, some other means of supplying the necessary pressure may be provided, such as pumps and elevated or hydropneumatic storage tanks. A typical pumped system utilizing a hydropneumatic storage tank is shown in figure 265.

Since reservoir levels at the low head plants are generally below the established minimum head for fire service and several of the reservoirs at the high head plants are subject to seasonal drawdowns for flood control purposes to levels where they would not provide the minimum fire pressure, a large number of fire-protection systems are supplied from the treated water system. Treated water is usually obtained from treatment plants located either in the powerhouse or nearby. In a few cases water is obtained from an adjacent municipality by the extension of a main line to the project from the city system. Large-capacity elevated storage tanks are always incorporated in these water systems to assure an ample supply.

Pumps and piping.—In some low head projects raw water pressure is maintained at 80 pounds per square inch for the fire-protection system by the installation of a hydropneumatic tank with float controls operating in echelon to actuate the starting and stopping of two centrifugal fire pumps. A 2,000-gallon pressure and storage tank is used, with the upper third of the tank volume filled with air from the station compressed-air system. This acts both as a surge and pressure chamber. An air pressure regulating valve is installed in the air supply line to the tank which serves to control the entire system pressure. Other systems involve the use of elevated storage tanks of sufficient capacity to provide an ample supply of water at an adequate pressure, with the water level main-

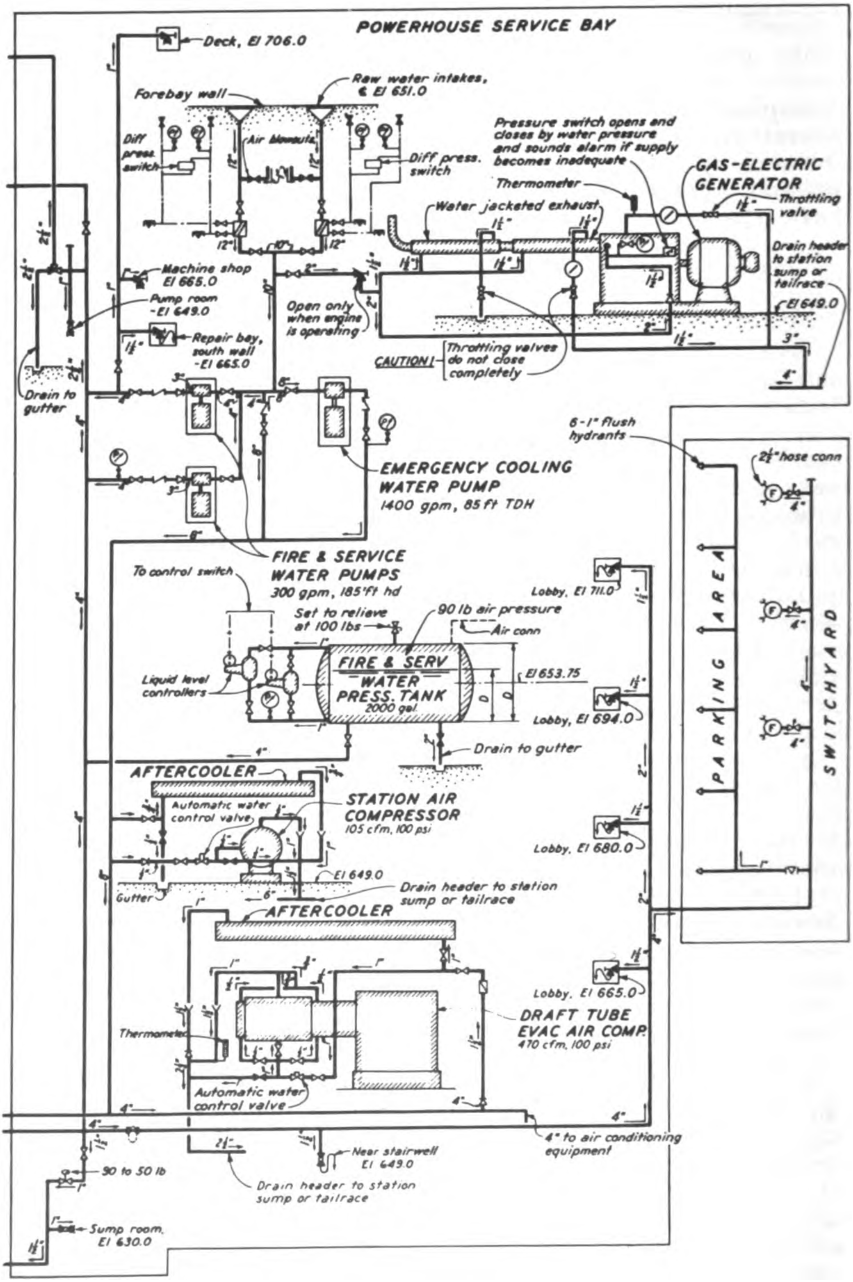


FIGURE 265.—*Hydropneumatic fire-protection system—Chickamauga.*

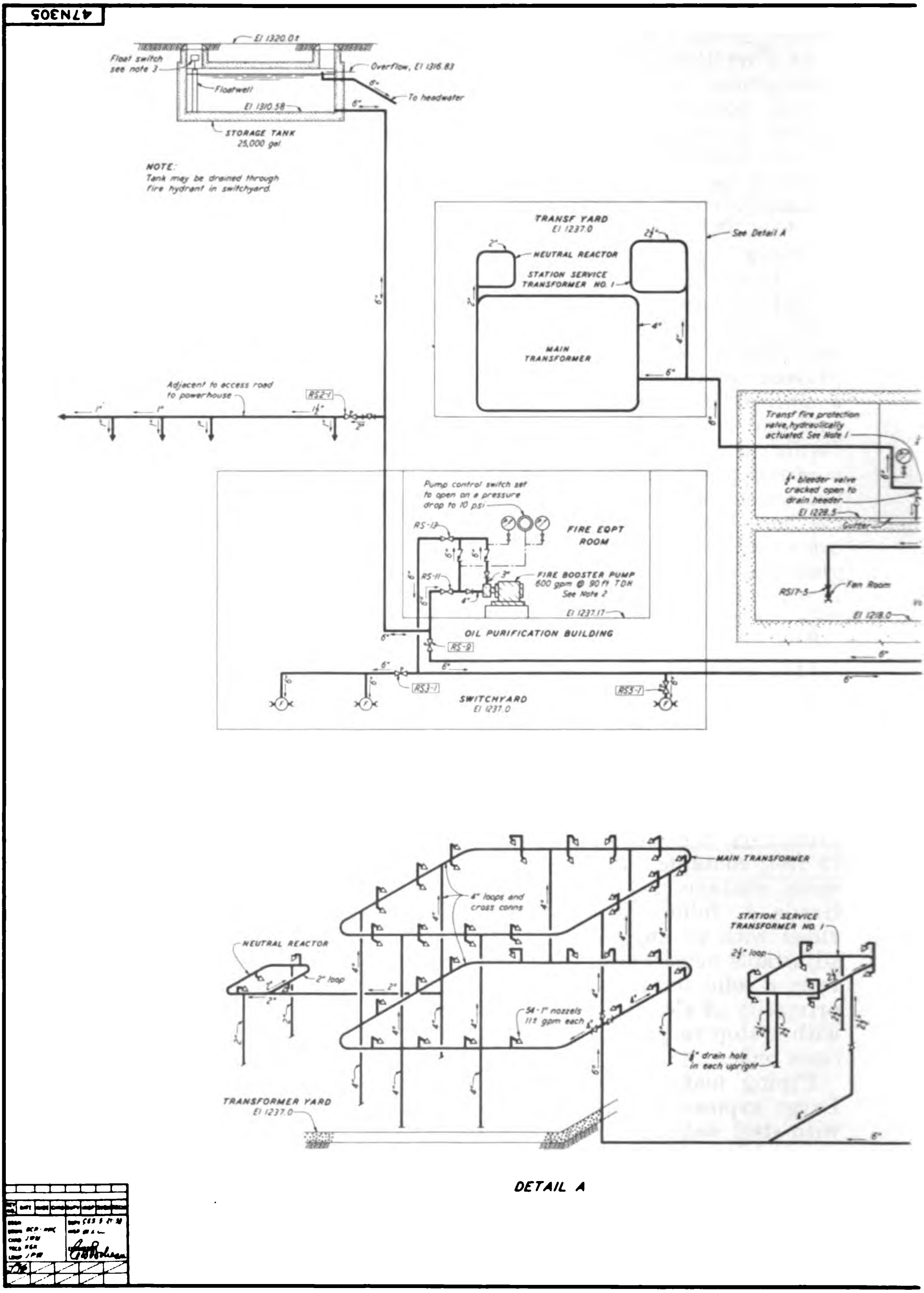
tained by a supply pump furnishing strained raw water from intakes in the forebay.

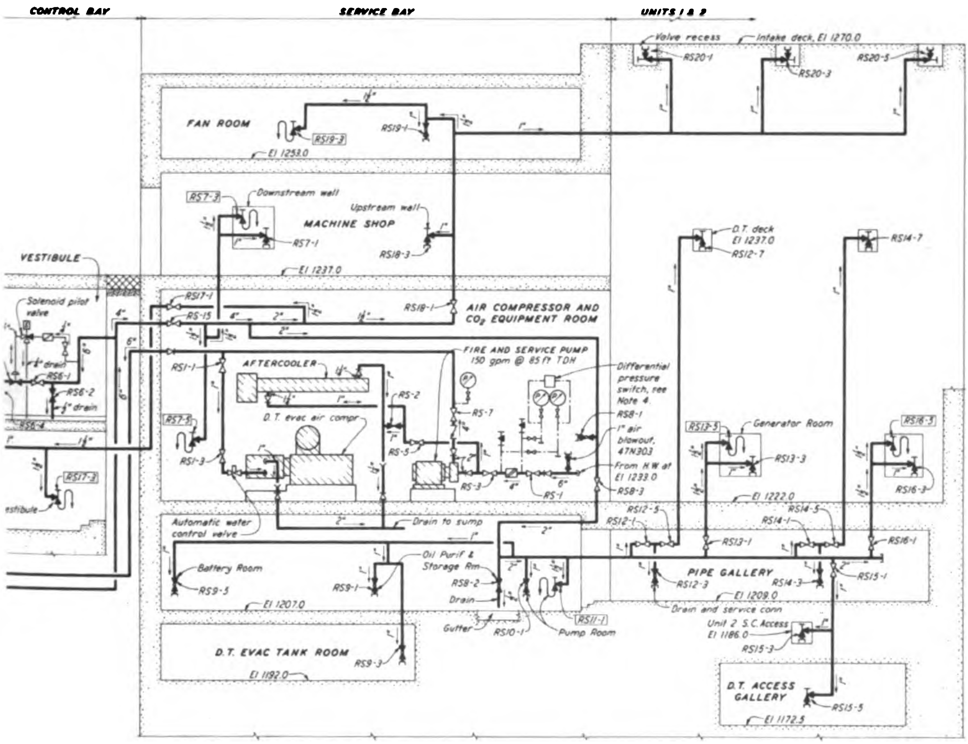
At Fort Patrick Henry project a large-capacity formed concrete underground storage tank is installed to supply a 600-gallon-per-minute booster pump. The booster pump is automatically controlled to supply the necessary pressure for operation of the transformer fire-protection system when the automatic fire-protection valve is opened, or remote-controlled from convenient push-button stations for use of hose lines. Plate 37 shows a flow diagram of the Fort Patrick Henry project fire-protection system.

Where raw water is used at headwater pressure, a separate intake from each unit penstock or from the forebay is usually connected into a central manifold from which the different plant raw water services are supplied at various water pressures. Each intake line is supplied with a cutoff gate valve, a check valve to prevent reverse flow from one penstock to another if required, and a multiple-basket twin strainer which may be cleaned under pressure and without service interruption. Water strainers are usually furnished with $\frac{1}{16}$- or $\frac{1}{8}$-inch perforated straining elements. A separate pressure regulating valve is usually installed in the fire-protection raw water line where excessive pressures may occur on the hose lines. These are ordinarily pilot-operated, pneumatically controlled valves. Regulating valve stations are provided with a globe valve bypass, pressure gage, and relief line, usually designed to maintain the outlet pressure between 60 and 80 pounds per square inch under all conditions of headwater levels.

The distribution system is essentially the same at all plants. The supply header, sized according to the total flow requirements of the system, is routed as direct as possible from source to hazard. Branch lines of $1\frac{1}{2}$-inch size supply the fire hose racks, which are either enclosed in cabinets or exposed and located at strategic points throughout the plant. Typical fire hose rack details are illustrated in figures 266 and 267, and figure 268 shows a view of one of these assemblies. Where water is considered the desirable medium of fire protection, the racks are spaced so that the length of hose, usually 75 feet, contained on the rack will reach all fire hazards. All hose racks contains $1\frac{1}{2}$-inch unlined linen hose, Underwriters' Label Grade A, folded on a steel-covered semiautomatic rack, and provided with an angle supply valve and a brass nozzle. Usually an adjustable nozzle, adjustable for the full range of stream conditions from a solid stream to fog, is installed. Where the hazard consists primarily of electrical equipment, however, the nozzles are equipped with a stop to prevent a solid stream or have the fog and off positions only.

Piping materials vary according to size and location of lines. Large exposed lines, 4-inch size and over, are of black steel pipe with steel welding fittings and forged steel flanged joints. Smaller exposed lines are generally of galvanized steel pipe with screwed, malleable-iron fittings and unions. Large embedded lines are cast-iron pipe and fittings with bell and spigot joints. Small embedded lines are genuine wrought-iron pipe with malleable-iron screwed fittings. Gate valves, $2\frac{1}{2}$ inches and larger, are rising stem, outside


El 1320.0±
Float switch
see note 3
Overflow, El 1316.83
6"
To headwater
Floatwell
El 1310.58
STORAGE TANK
25,000 gal
NOTE:
Tank may be drained through
fire hydrant in switchyard.
TRANSF YARD
El 1237.0
See Detail A
NEUTRAL REACTOR
STATION SERVICE
TRANSFORMER NO. 1
MAIN
TRANSFORMER
Adjacent to access road
to powerhouse
RS2-1
Transf fire protection
valve, hydraulically
actuated. See Note 1
bleeder valve
cracked open to
drain header
El 1228.5
Gutter
RS17-5
Fan Room
El 1218.0
Pump control switch set
to open on a pressure
drop to 10 psi
RS-13
RS-11
FIRE EQPT
ROOM
FIRE BOOSTER PUMP
600 gpm @ 90 ft TDH
See Note 2
El 1237.17
OIL PURIFICATION BUILDING
RS-9
RS3-1
RS5-1
SWITCHYARD
El 1237.0
MAIN TRANSFORMER
4" loops and
cross conns
STATION SERVICE
TRANSFORMER NO. 1
2½" loop
NEUTRAL REACTOR
2" loop
54-1" nozzels
111 gpm each
drain hole
in each upright
TRANSFORMER YARD
El 1237.0
DETAIL A



POWERHOUSE

NOTES:

1. OPERATION OF TRANSFORMER SPRINKLER SYSTEM
   The transformer fire protection valve auxiliary relay is operated by the following:
   - A - Transformer differential relay
   - B - Transformer thermostats
   - C - Emergency manual switch near transformer.
   - D - Test switch located on main control board

   When transformer fire protection valve auxiliary relay operates the following functions are performed.
   - A - Transformer fire protection valve opens
   - B - Fire booster pump starts
   - C - Transformer blowers stop
   - D - Annunciation at Boone Control Building

   The transformer sprinkler system is shut off by the ON-OFF-TEST switch on main control board
2. OPERATION OF FIRE BOOSTER PUMP
   Fire booster pump operates as follows.
   - A - Starts automatically when transformer sprinkler system is turned on
   - B - Started and stopped from manual control station located near pump for switchyard fire hydrant use
   - C - Started manually for powerhouse fire hose use from push button station located in control room. Stopped by operating ON-OFF-TEST switch on control board to OFF position momentarily
   - D - Stopped by low pressure switch on suction of pump indicating that storage tank is empty
3. SINGLE TANK FLOAT SWITCH CONTROLLING 150 GPM FIRE AND SERVICE PUMP OPERATIONS
   - El 1316.67 - High level alarm sounds at Boone Control Building
   - El 1316.42 - High level alarm stops and pump stops
   - El 1315.17 - Pump starts
   - El 1314.42 - Low level alarm stops.
   - El 1314.17 - Low level alarm sounds at Boone Control Building

   Differential pressure switch operates low flow alarm at Boone Control Building, on pressure drop from normal of 1 to 3 psi, to notify operator when strainer needs cleaning.

REFERENCE DRAWING:

47BM300...BILL OF MATERIAL - VALVE MARKER TAGS.
47N300....VALVE OPERATION DIAGRAM - SYMBOLS & INDEX

GENERAL

VALVE OPERATION DIAGRAM
RAW WATER SYSTEM
FIRE & SERVICE

FORT PATRICK HENRY PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	9-?-53	32	M	4	47N305 R0

screw and yoke type with flanged iron body, double-disc gate, and bronze mounting. Smaller gate valves are also rising-stem type with bronze body, screwed ends, and solid wedge disc. Angle valves at the hose racks are screwed bronze body valves with bronze discs.

Lines are insulated where sweating or condensation would prove objectionable, such as pipes over suspended ceilings or electrical equipment. Lines subject to freezing are also insulated. The thickness of antisweat insulation depends on the temperature of the water passing through the line and the humidity of the ambient air. In general, insulation of 1-inch thickness will prevent sweating at the low head hydro plants. At the high head plants, where water temperatures range as low as 36° F., 1½-inch-thick insulation is applied. Standard commercial insulating felt either in roll form or premoulded in 3-foot sections is used. The insulation is covered with an 8-ounce canvas jacket. Built-up hairfelt is applied to pipelines subject to freezing, with a weatherproof jacket over the insulation where the lines are exposed to the weather.

CO_2 systems

The typical carbon-dioxide fire-protection system includes an assembly of 50-pound capacity, 850-pound-per-square-inch pressure, carbon-dioxide cylinders. Figure 269 shows the cylinder racks, routing valves, and piping at Apalachia powerhouse. Liquid carbon dioxide is stored at room temperature and is automatically discharged and routed through valves and permanent piping to the protected space, where it is discharged through nozzles arranged to provide uniform gas distribution. A sufficient number of cylinders are provided to obtain a concentration of not less than 50 percent within generator housings and of not less than 22 percent in other protected hazards in rooms or enclosures, assuming 1 pound of liquid carbon dioxide will occupy about 8 cubic feet as a gas.

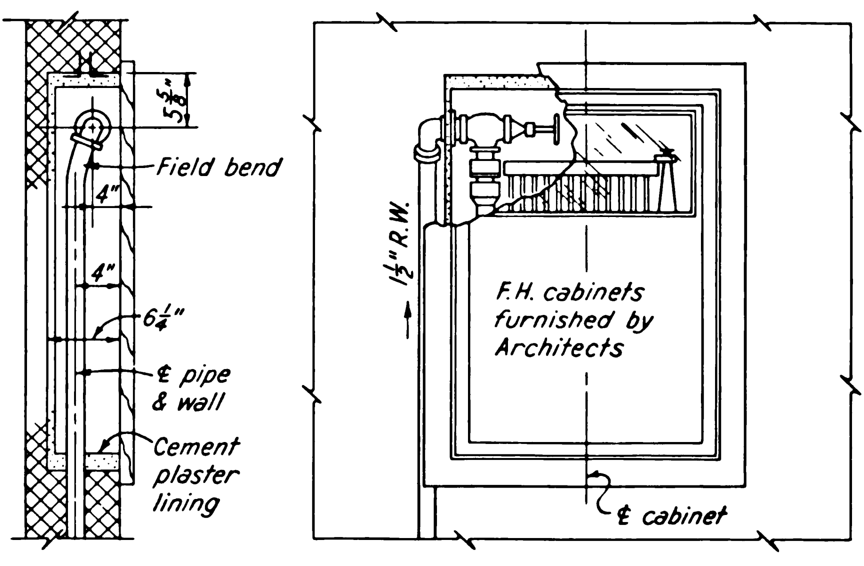


FIGURE 266.—*Typical fire hose cabinet details.*

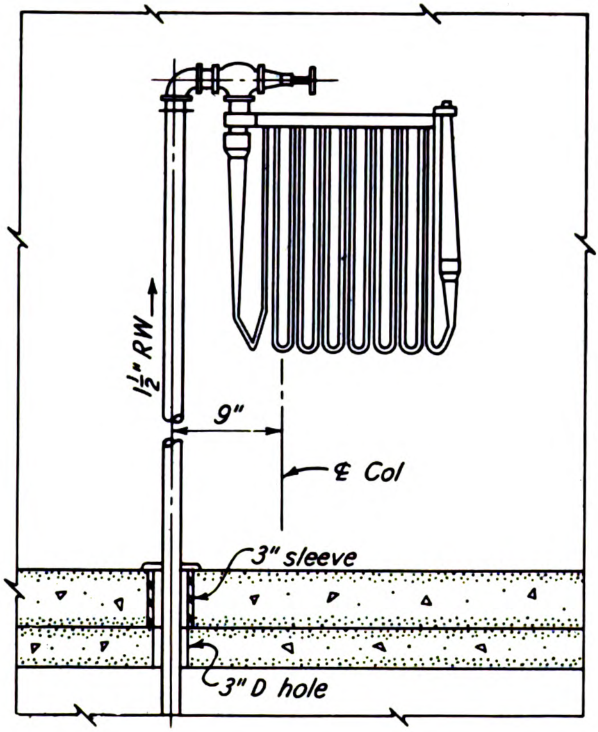


FIGURE 267.—*Typical exposed fire hose rack.*

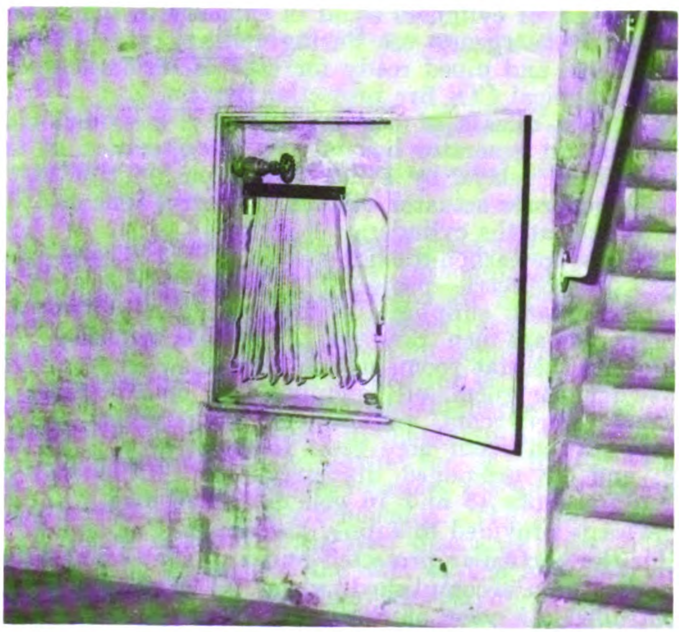


FIGURE 268.—*Fire hose cabinet—Fontana.*

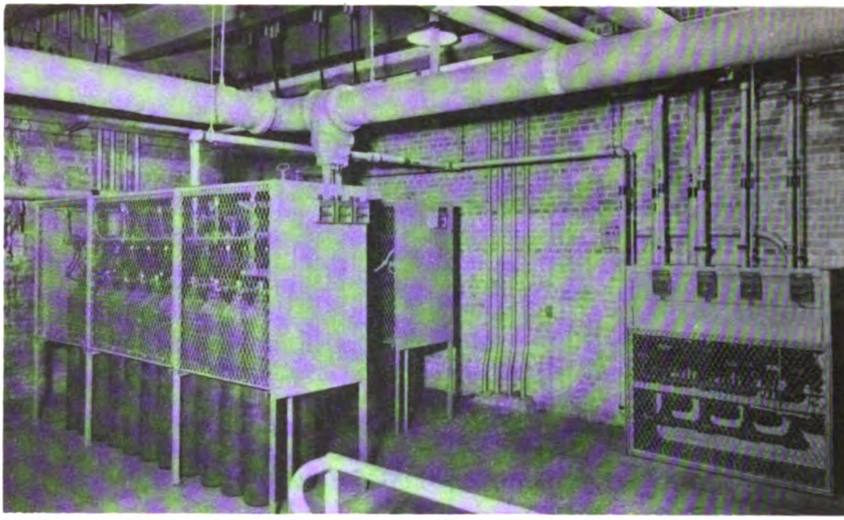


FIGURE 269.—*High pressure system CO_2 cylinder banks and distributing valves—Apalachia.*

If it is necessary to maintain the carbon-dioxide concentration over a period of time to prevent rekindling, a delayed discharge is also provided to maintain, in generator housings, a concentration of not less than 25 percent for 30 minutes. Delayed discharge may be either continuous or intermittent; usually the cylinders in the delayed discharge bank are released intermittently by a cam-operated release mechanism.

A reserve bank of cylinders equal in capacity to the initial bank is provided for emergency use during refilling of used cylinders. These are racked and piped ready for use. Plate 38 is a schematic diagram of a typical CO_2 fire protection system.

Control of the release of carbon dioxide is provided either by thermostats in the generator housing, by the operation of the generator differential relays, by a break-glass push-button station located on the governor actuator cabinet or control benchboard, or by a manual release at the cylinders.

One low-pressure carbon-dioxide system is in service at present at Hales Bar hydroelectric project. A 4-ton refrigerated carbon-dioxide storage tank supplies the fire-protection system at about 300-pound-per-square-inch pressure. This has capacity for total flooding of the rheostat room, station service switchgear room, 6.6-kilovolt switchgear room, oil pumping and reactor room, station service transformer room, and enclosed transformer bank 4; by manual application from hose reels for open-type units 1 to 14, inclusive; and by prolonged discharge with initial and delayed application for units 15 and 16 generator housings. A discharge timing device is provided to supply the required amount of carbon dioxide for the particular protected unit and shut off the discharge when this has been accomplished, where the discharge is automatically controlled. A view of the refrigerated CO_2 storage tank at Hales Bar is shown in figure 270.

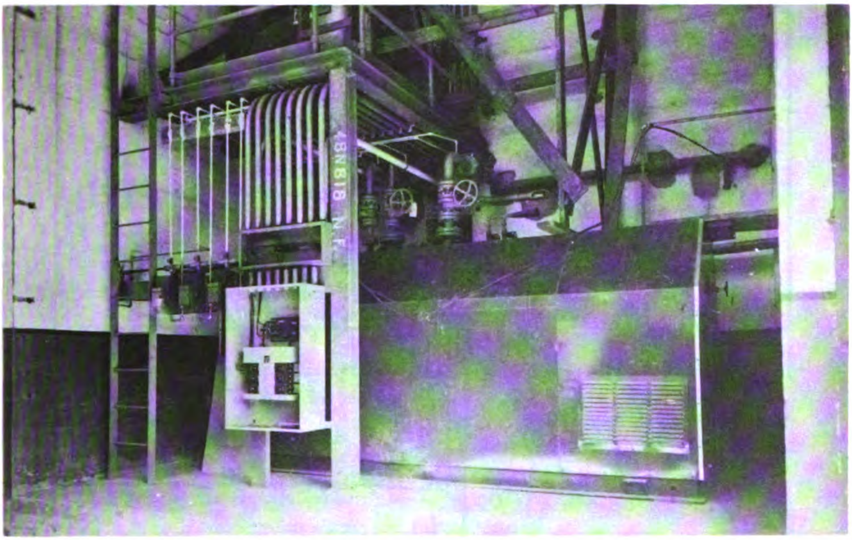


FIGURE 270.—*Low-pressure system refrigerated CO_2 storage tank—Hales Bar.*

In both high- and low-pressure carbon-dioxide systems various auxiliary devices, such as pressure switches, door or vent damper pressure trips, or screening nozzles, may be used where required to isolate the fire to the protected space.

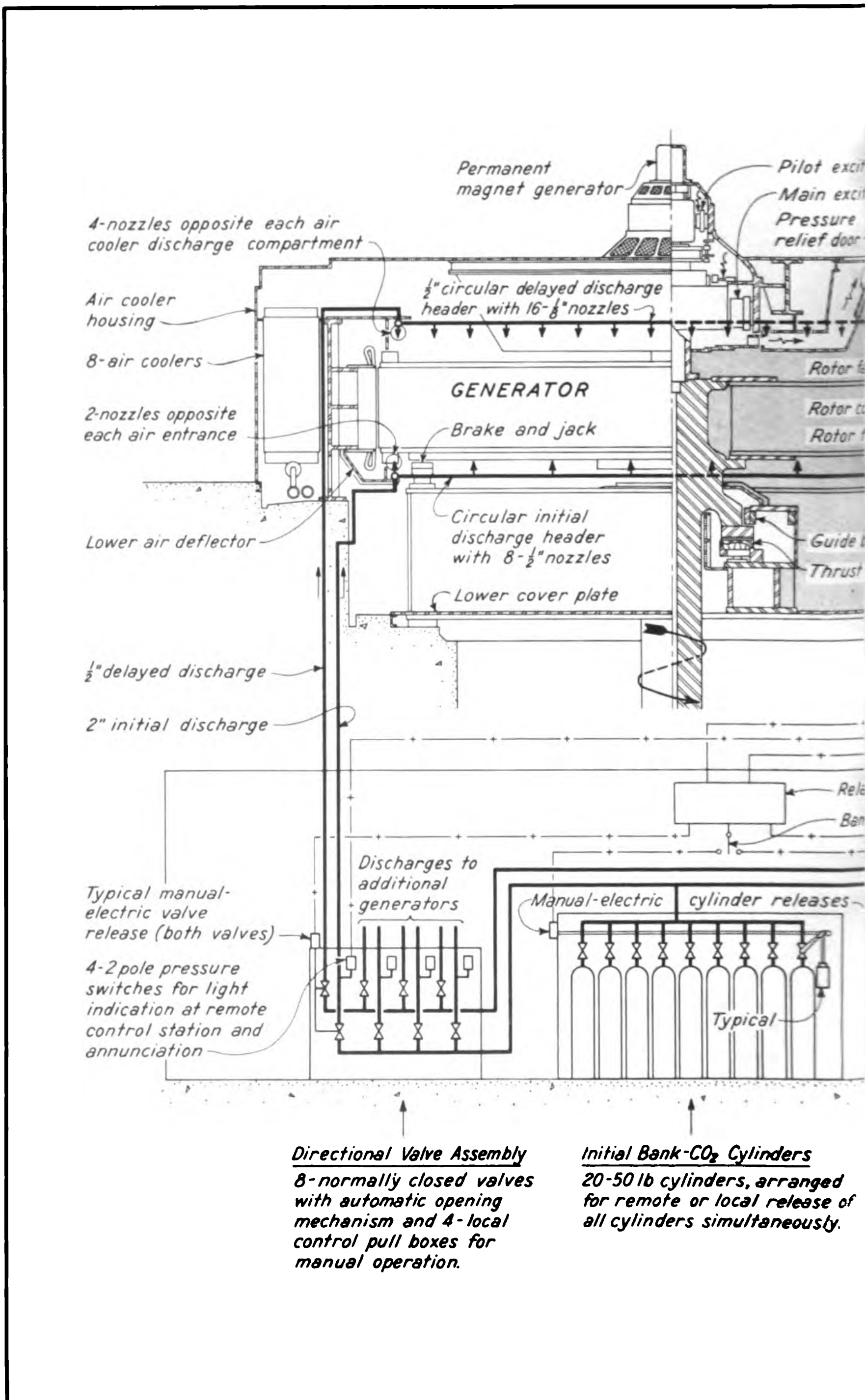
Piping systems are designed to meet the standards of the National Fire Protection Association for carbon-dioxide fire-extinguishing systems.

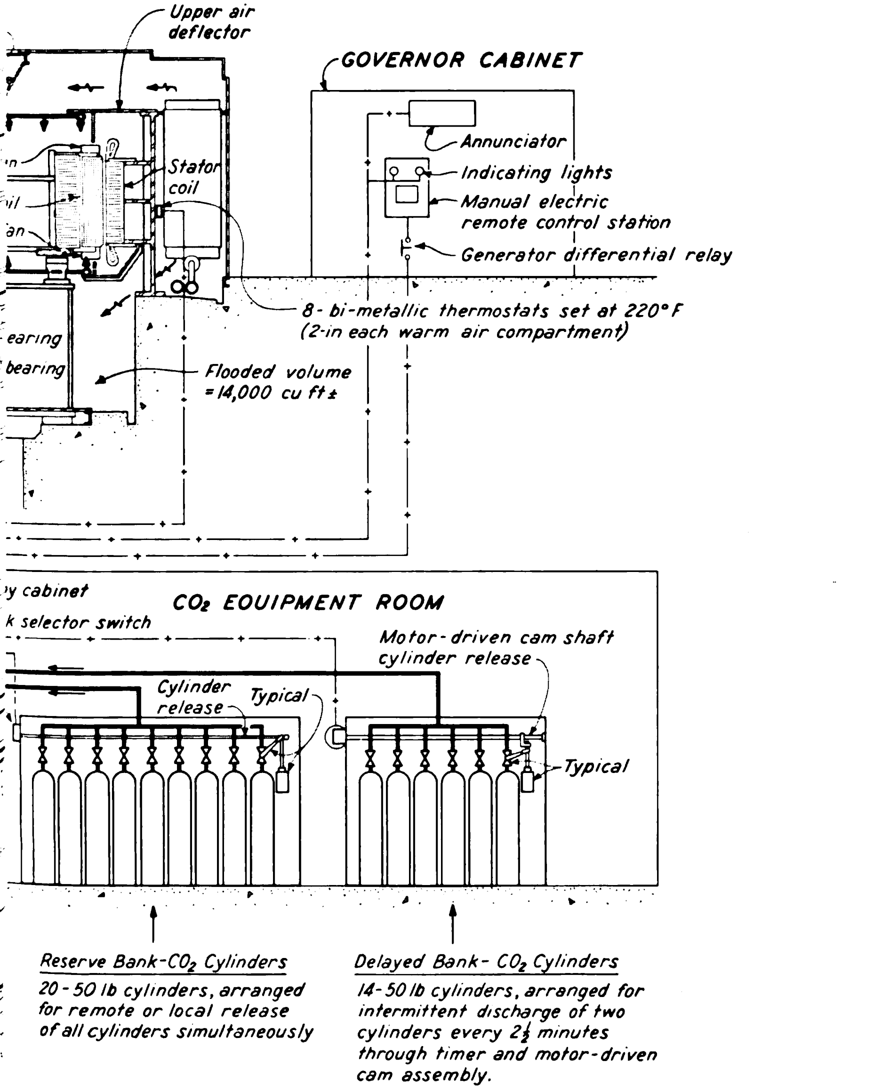
Carbon-dioxide extinguishing systems are classified according to method of application as follows:

Class A—Protection of equipment by the total flooding of enclosed spaces.
Class B—Protection of equipment by local application of gas on particular hazards.
Class C—Protection of equipment where an initial and delayed discharge of gas is required.

Generators.—The typical water-cooled generator installation with enclosed air housing employs a class C carbon-dioxide extinguishing system with initial total flooding of the air housing followed by intermittent delayed discharge to prevent rekindling. An initial discharge of 1 pound of gas for each 10 cubic feet for spaces up to 2,000 cubic feet and 1 pound of gas for each 12 cubic feet for larger spaces is provided. The delayed discharge is provided with either continuous or intermittent discharge to maintain a concentration of 25 percent of carbon dioxide for 30 minutes. The number, type, and location of discharge nozzles are such as to give uniform gas distribution in the air housing. The total area of discharge orifices on initial and delayed discharge lines is equal to between 40 and 85 percent of the sum of the minimum areas of the gas release devices released simultaneously.

For open units without enclosed air housings there are means for extinguishing fires by manual application of carbon dioxide from hose nozzles.


Permanent magnet generator
Pilot excit
Main excit
Pressure relief door
4-nozzles opposite each air cooler discharge compartment
Air cooler housing
8-air coolers
½" circular delayed discharge header with 16-⅛" nozzles
GENERATOR
Rotor fa
Rotor co
Rotor r
2-nozzles opposite each air entrance
Brake and jack
Circular initial discharge header with 8-½" nozzles
Lower air deflector
Guide b
Thrust
Lower cover plate
½" delayed discharge
2" initial discharge
Rele
Ban
Discharges to additional generators
Typical manual-electric valve release (both valves)
Manual-electric cylinder releases
4-2 pole pressure switches for light indication at remote control station and annunciation
Typical
Directional Valve Assembly
8-normally closed valves with automatic opening mechanism and 4-local control pull boxes for manual operation.
Initial Bank-CO₂ Cylinders
20-50 lb cylinders, arranged for remote or local release of all cylinders simultaneously.



GENERATOR FIRE PROTECTION

TYPICAL SCHEMATIC DIAGRAM OF CO_2 SYSTEM

Rooms or enclosures.—Where the fire hazard may be isolated to a reasonably small space, such as a room or compartment, and does not fall under the category of rotating electrical machinery, a class A carbon-dioxide extinguishing system is utilized. This method provides for total flooding of the room or enclosure so as to obtain about 25 percent concentration of carbon dioxide. By releasing a given number of cylinders for the high-pressure systems, or by a timing device on the discharge of the low-pressure system, the following minimum quantities of gas are provided:

Spaces up to 1,600 cubic feet—1 pound per 16 cubic feet
Spaces up to 4,500 cubic feet—1 pound per 18 cubic feet
Spaces up to 50,000 cubic feet—1 pound per 20 cubic feet
Spaces over 50,000 cubic feet—1 pound per 22 cubic feet

All doors, windows, exhaust ducts, and other openings are automatically closed where possible or screening nozzles are provided.

Oil purification and storage rooms, auxiliary generator rooms, transformer rooms, switchgear rooms, and other similar hazards are usually protected by the total flooding method. Figure 271 shows the CO_2 fire-protection outlets in the oil purification room at Fontana project.

Portable extinguishers

The most commonly used hand fire extinguisher in the powerhouses is the carbon-dioxide unit, normally obtained in the 5- or 15-pound size. These units have an extinguishing agent which is a nonconductor of electricity, is not subject to freezing, is nontoxic, leaves no residue, and is noninjurious to electrical insulation. However, a 15-pound-size unit, which is most commonly used, has an effective range of only 6 feet and will be exhausted in about 40 seconds. Each unit is furnished complete with hose, discharge horn, shutoff valve, and wall bracket. The units are conspicuously located throughout the powerhouse with, roughly, one extinguisher for each 2,500 square feet of floor area in accordance with the dictates of

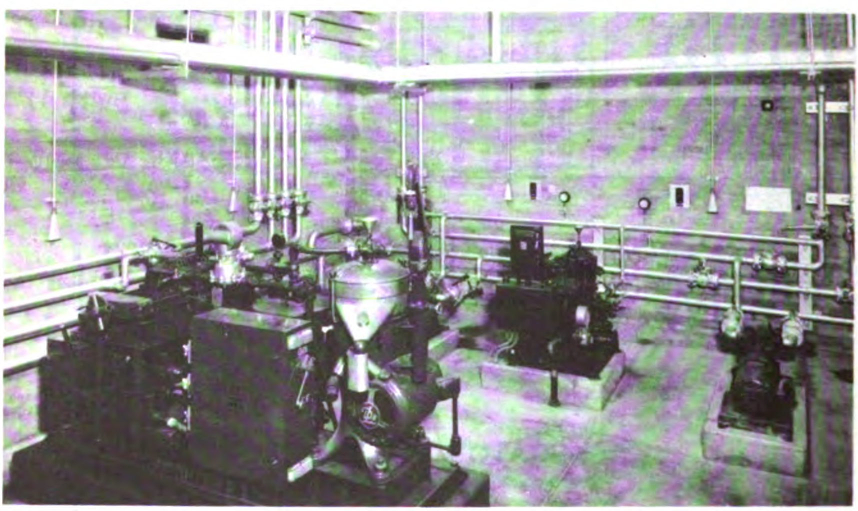


FIGURE 271.—*CO_2 fire protection outlets on wall of oil purification room—Fontana.*

hazards in various parts of the building. The extinguishers are weighed at least once annually to detect leakage or accidental release. If weight loss is 10 percent or more of their rated capacity, they are recharged.

Other types of portable fire extinguishers are provided upon the recommendation of the local safety officer or at the discretion of the individual plant superintendent. These include fire-extinguisher types such as the carbon tetrachloride, soda-acid, foam, water, sand, dry chemical, fire pails, and barrels as may be deemed necessary.

SWITCHYARD EQUIPMENT PROTECTION

Water systems

Switchyards located at or adjacent to TVA hydro plants are usually protected from fire by a water hydrant system. Two small remote-controlled stations depend on portable carbon-dioxide extinguishing equipment. Where water is the extinguishing agent, the supply is obtained from the same system which serves the powerhouse fire-protection system. The switchyard systems are designed to deliver a minimum of 250 gallons per minute from any hydrant at a minimum pressure of 40 pounds per square inch at the hose nozzle. The system usually consists of a 4- or 6-inch main installed in the ground below the frost line running the full length about in the center of the yard. The hydrants are usually spaced about 200 feet apart, so arranged that a fire in any particular piece of equipment may be approached from two sides with two 50-foot hose lengths. A minimum distance of 50 feet from any electrical equipment protected is maintained insofar as possible so that a fire would not block the use of any hydrant.

A fire hose cart (fig. 272), equipped with a reel and two 50-foot lengths of 2½-inch hose, is in each switchyard. Where the switchyard is of considerable length, two carts are furnished, located at each end of the yard near entrance gates.

Piping.—The piping system is of centrifugally cast, class 150, cast-iron pipe with bell and spigot joints. The pipe and fittings are coated inside and outside with coal-tar varnish, thus reducing friction loss, preventing internal corrosion and tuberculation, and increasing the length of life of the pipe. Hydrants are of the compression, nonfreezing, barrel type, fitted with two 2½-inch capped hose nozzles with National Standard Fire Hose Threads. All interior working parts may be removed through the barrel from the top. Approximately 3 cubic feet of gravel is placed around the bottom of the hydrant to facilitate draining, after use, through small holes provided in the bottom bell above the valve seat.

Gate valves are usually installed in the branch lines serving each hydrant. Sectionalizing valves in the system are standard AWWA, double-disc gate, iron body, bronze-mounted, nonrising stem type, with operating nut for extension stem operation. The valves are equipped with cast-iron adjustable valve box and cover flush at the ground surface.

The fire hose cart is usually stored in a small concrete building, specially designed by the TVA to house fire-protection equipment

(fig. 272). The building also houses portable carbon-dioxide extinguishing equipment. The hose cart is fitted with a tool box containing two spanner wrenches, one hydrant wrench, two adjustable hose nozzles and playpipes, and reel containing 100 feet of 2½-inch hose. The adjustable hose nozzle, with an integral stop to prevent a solid stream, has a range of adjustment from approximately a 150-degree angle, or full curtain, down to a 15-degree conical angle. This permits the operator to initially attack a fire with a small cone spray and long throw, and to increase the conical angle to provide an effective curtain or screen for closer approachment. The adjustable nozzle also permits the stream to be completely shut off at the nozzle.

Portable extinguishers

Each switchyard has at least one portable wheeled- or buggy-type carbon-dioxide extinguisher. Larger yards and yards constructed on more than one level are provided with two or more portable carbon-dioxide extinguishers. Each unit consists of two 50-pound cylinders with 40 feet of connected hose and a shielded discharge horn mounted on a wide-tread rubber-tired wheel assembly. Penetrating seal disc-type valves are furnished with the cylinders. Nozzle and releases are specially designed for fast action. The 100-pound unit has a range of about 8 feet and discharges completely in approximately one minute. The long grip handle of the discharge horn is equipped with a shutoff valve which allows the operator to shut off the flow when changing position. The complete wheeled assembly weighs about 500 pounds.

The cylinders are weighed periodically and recharged in the same manner as other carbon-dioxide extinguishers in the powerhouse. Spare cylinders are available from the reserve bank in the powerhouse for replacing those discharged.

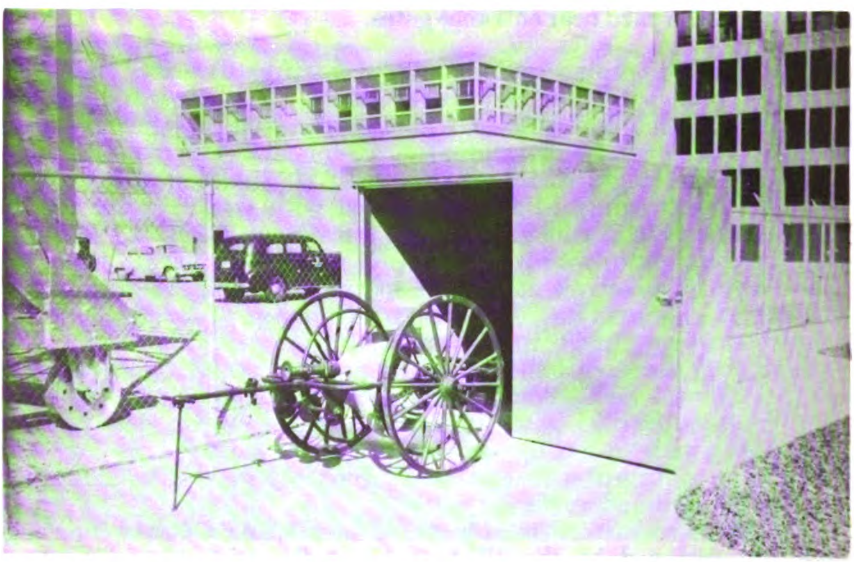


FIGURE 272.—*Switchyard fire hose cart and equipment building—Fontana.*

TRANSFORMER PROTECTION

Where outdoor electrical equipment is so located that it represents a definite fire hazard to adjacent equipment or building structures, a fixed-type fire-protection system is justified. These are classified as either water-spray- or fog-type systems, depending on nozzles and pressures utilized. The water-spray-type system is regarded as a low-pressure system ranging from 30 to 80 pounds per square inch at the nozzle and utilizing a spray nozzle which produces a conical solid spray pattern from spiral or a combination of straight and spiral streams of water emerging from a single discharge orifice. The water-fog-type system is designed for operation with approximately 100 pounds per square inch at the nozzle and utilizes a fog nozzle which produces a conical solid pattern of smaller particles from multiple sets of impinging jets, usually with three orifices per set.

Automatic control is usually provided, with manual control only where the character of the hazard and availability of trained personnel makes automatic operation unnecessary. Fire-protection systems recently designed or proposed are of the automatic fog-nozzle type.

The fixed nozzle systems utilize exterior supply piping subject to freezing. This piping is normally dry, with water admitted in case of fire by an automatic or manual-operated deluge valve. Strainers are ordinarily provided to prevent clogging the nozzles.

As recommended by the National Fire Protection Association, the following minimum distances between nozzles and high tension lines are maintained:

Phase to ground voltage, volts:	*Span feet*
19,000	4
38,000	6
76,000	8
127,000	14

Only one serious transformer fire at TVA hydroelectric stations is recorded to date. In September 1949, at Wilson hydro plant, failure of C-phase of 13.8/161-kv. transformer bank No. 11 threw oil on transformer bank No. 12 which ignited, causing damage of $25,300 to bank No. 12 and other equipment. This fire was extinguished by the fixed manual-operated water-spray system. Figure 273 is a view, taken shortly after the fire, of the area where the fire occurred.

Water spray systems

Following are discussions of specific fixed installations of spray-type transformer fire-protection systems at Wilson, Wheeler, Watauga, and Fort Patrick Henry projects.

Wilson project.—At this project the main power transformer banks are outdoors in two switchyards, one on each side of the switch building. The banks and distance between phases are somewhat closer than are established in present-day design. There are

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nine banks of single-phase transformers for the 18 generating units, each bank serving 2 units.

The four water-cooled transformer banks initially installed in 1925 to serve generating units 1 to 8 have since been replaced or altered. Three banks now consist of three oil-insulated, forced-oil and air-cooled, single-phase transformers rated at 27,500 kva. These transformer banks are individually rated at 82,500 kva. and 13.8/161 kv. One of the original four transformer banks now serves the 46-kv. switchyard and consists of three oil-insulated, single-phase transformers rated at 20,000–26,667 kva. This bank is individually rated at 60,000 kva., self-cooled, or 80,000 kva., forced-air-cooled, and 12.3/46 kv.

In 1942 and 1943, six additional generators with their three transformer banks were added to the station. These transformer banks are individually rate at 49,500 kva., self-cooled, or 66,000 kva., forced-air-cooled, and 13.8/161 kv. Each bank consists of three oil-insulated, single-phase transformers rated at 16,500–22,000 kva.

At this time a fixed, manually operated, water-spray fire-protection system was installed for the seven existing transformer banks.

In 1949, the four remaining generators with their two transformer banks were added to complete the power installation, and the fixed fire-protection system was extended to include these two banks. The new transformer banks are individually rated at 49,500 kva., self-cooled, or 66,000 kva., forced-air-cooled, and 13.8/161 kv. Each bank consists of three oil-insulated, single-phase transformers rated at 16,500–22,000 kva.

The fire-protection system is supplied with raw water from a 40,000-gallon elevated storage tank which was originally installed to provide cooling water for the water-cooled transformers and other equipment. The tank supply is automatically maintained by four large-capacity pumps which had also been previously installed.

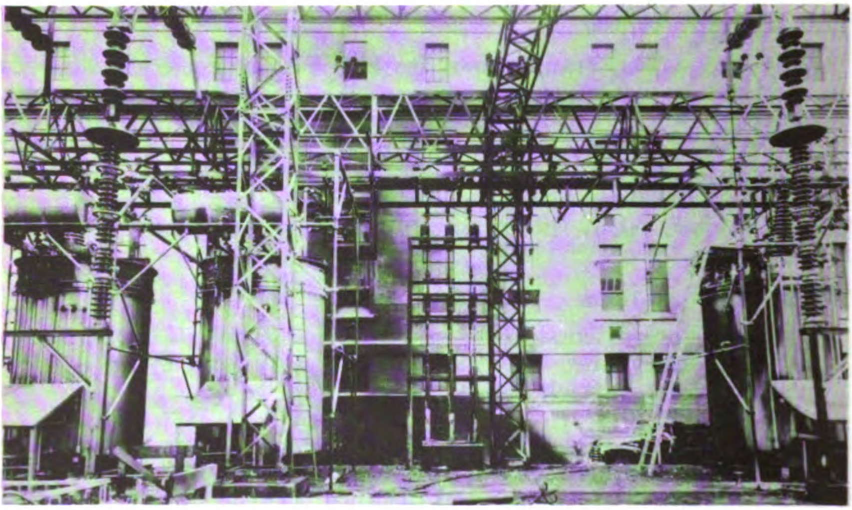

FIGURE 273.—*Area of September 1949 fire at Wilson hydro plant caused by transformer failure—A and B phases of transformer bank No. 12, at left, and the C phase, which failed, of bank No. 11, at right—view taken shortly after the fire.*

Since the static pressure provided by the tank was insufficient, two fire pumps drawing water from the storage tank were installed to boost the pressure and provide the required amount of water in the fire-protection system. A basket-type water strainer is installed in the common suction line to these pumps. Each pump is a motor-driven, horizontal, centrifugal, single-stage, double-suction pumping unit with a capacity of 750 gallons per minute at a total dynamic head of 120 feet. The pumps, which are located in the basement of the switch house, discharge into a common 6-inch supply main with 6-inch branch lines to the nozzle system at each of the nine transformer banks.

A 6-inch lever- and manually-operated gate valve with improvised operator is provided in each branch line. These valves, shown in figure 274, are located on the second floor of the switch house near windows overlooking the transformer bank being served. Manual push-button stations with indicating lights for controlling both fire pumps are provided near each of the nine gate valves; push-button stations are also provided at the pumps.

Each system at the transformers consists of overhead pipe loops and lower headers at about half the transformer height, with a total of from 51 to 57 nozzles for each bank. Each bank includes a neutral reactor for which either three or four nozzles are provided for protective coverage. The nozzles are 1-inch size, of the center-jet stationary-turbine type and deliver approximately 15 gallons per minute at 40 pounds per square inch in the form of a solid cone. This arrangement will provide a total flow of approximately 765 gallons per minute to any individual transformer bank using one fire pump.

Although the second fire pump is considered a standby, it is possible to operate the two pumps in parallel to spray two transformer banks with a total flow of approximately 1,500 gallons per minute. Automatic drainage of the outdoor piping prevents freezing.

The main control room for this plant is several hundred feet distant from the switchyard, making visual observation by the operators of all transformer banks difficult. Each transformer, however, has control room annunciation for high oil and coil temperature. Transformer differential relays are also provided to automatically disconnect a faulty transformer from the system. In addition, annunciation of low water level in the elevated water storage tank is made in the control room.

Wheeler project.—Four banks of single-phase transformers serve the eight generating units at Wheeler project, each bank serving two units. The four banks are located adjacent to the outdoor-type generators on the draft tube deck of the powerhouse. Three transformer banks are individually rated at 72,000 kva., self-cooled, or 84,000 kva., forced-air-cooled, 13.8/161 kv., and consist of three oil-insulated, single-phase transformers rated at 24,000–28,000 kva. The other, bank No. 3, is individually rated at 63,000 kva., self-cooled, or 84,000 kva., forced-air-cooled, 13.8/161 kv., and consists of three oil-insulated, single-phase transformers rated at 21,000–28,000 kva. Because of the wide spacing of banks, no fire wall between each bank is necessary. Spilled oil will drain from large

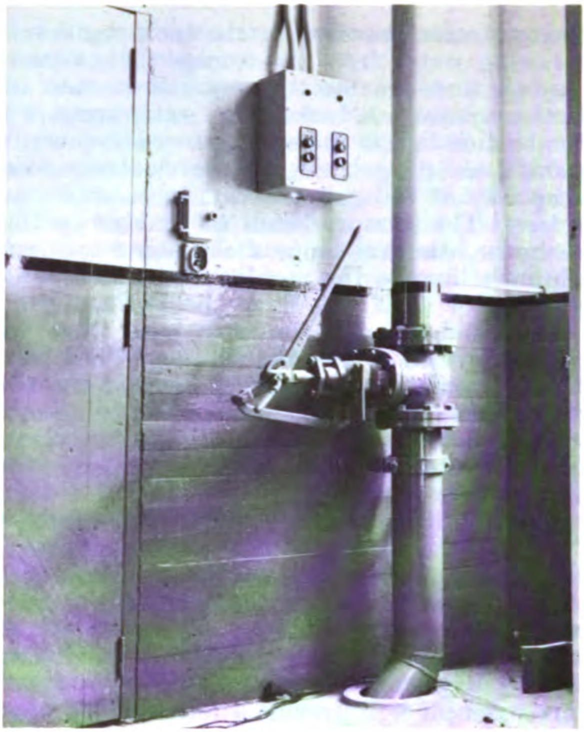

FIGURE 274.—*6-inch, lever-operated, quick-opening type transformer fire-protection control valve—Wilson.*

sumps beneath each transformer through 8-inch drains to the tail-race.

The fire-protection system is supplied with treated water from the 25,000-gallon elevated storage tank located in Wheeler Village. A flow diagram of the fire-protection system for transformer bank No. 2 is shown in figure 275.

A transformer fire pump drawing water from a 6-inch main in the treated water system is provided to maintain a flowing pressure of approximately 30 pounds per square inch at the nozzles. The pump is a motor-driven, centrifugal, single-stage, single-suction unit with a capacity of 800 gallons per minute at a total dynamic head of 190 feet. The pump has a 6-inch check valve bypass to supply other treated water services not requiring pump operation. The pump, which is located near the clearwells in the service bay at elevation 498.5, discharges into a 6-inch header with 6-inch branch lines to the fixed spray system at each of the four transformer banks. A 6-inch gate valve located in the transformer sprinkler valve room at elevation 525 controls the supply to each transformer bank. A manual push-button station for controlling the fire pump is provided near each of the four gate valves.

Each system at the transformers consists of overhead pipe loops at elevation 540 and lower headers at about half the transformer height, with a total of 42 nozzles for each bank. The spray nozzles

are 1¼-inch size with ⅜-inch orifice and deliver approximately 19 gallons per minute at 30 pounds per square inch in the form of a solid cone. This arrangement will provide a total flow of approximately 800 gallons per minute to any individual transformer bank with the fire pump in operation.

In addition, there are several 2½-inch hose valves along the transformer deck and on the observation deck overlooking the generators to which hose may be attached for hand firefighting purposes.

Watauga project.—Two main transformers serving the two generating units are located adjacent to the downstream wall of the powerhouse on the transformer deck. These are each rated at 24,000 kv.-a., self-cooled, or 32,000 kv.-a., forced-air-cooled, 13.8/69 kv., and are 3-phase, oil-insulated.

The transformer sprinkler fire-protection system is supplied with raw water at unreduced pressure from the penstock. A flow diagram of this automatically controlled spray system is shown in figure 276 and a schematic arrangement of the system is shown in figure 277.

The static pressure at the nozzles may vary between a minimum of 60-pound-per-square-inch pressure and normal of 120-pound-per-square-inch pressure, depending on headwater elevation. Twin strainers having 1/16-inch perforations are provided in the supply to the 10-inch header. Two 6-inch branch lines, each with a solenoid-pilot-operated diaphragm motor valve for automatic operation of the system, furnish raw water to the fixed spray nozzles. An upper and a lower 4-inch pipe loop provides distribution of 64 spray nozzles, incuding several nozzles for protective coverage of the generator leads housing and neutral reactor at each transformer. The 1-inch nozzles with a spray angle of 70 degrees will deliver approximately 19 gallons per minute at a flowing pressure of 50 pounds per square inch at the nozzle or 23 gallons per minute at 75 pounds per square inch. Roughly, 1,200 gallons per minute

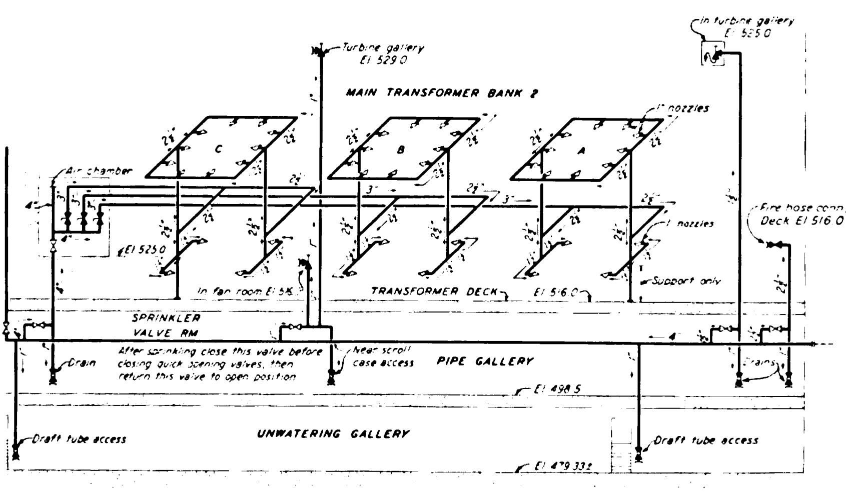

FIGURE 275.—***Flow diagram of manually operated water spray fire protection system for transformer—Wheeler.***

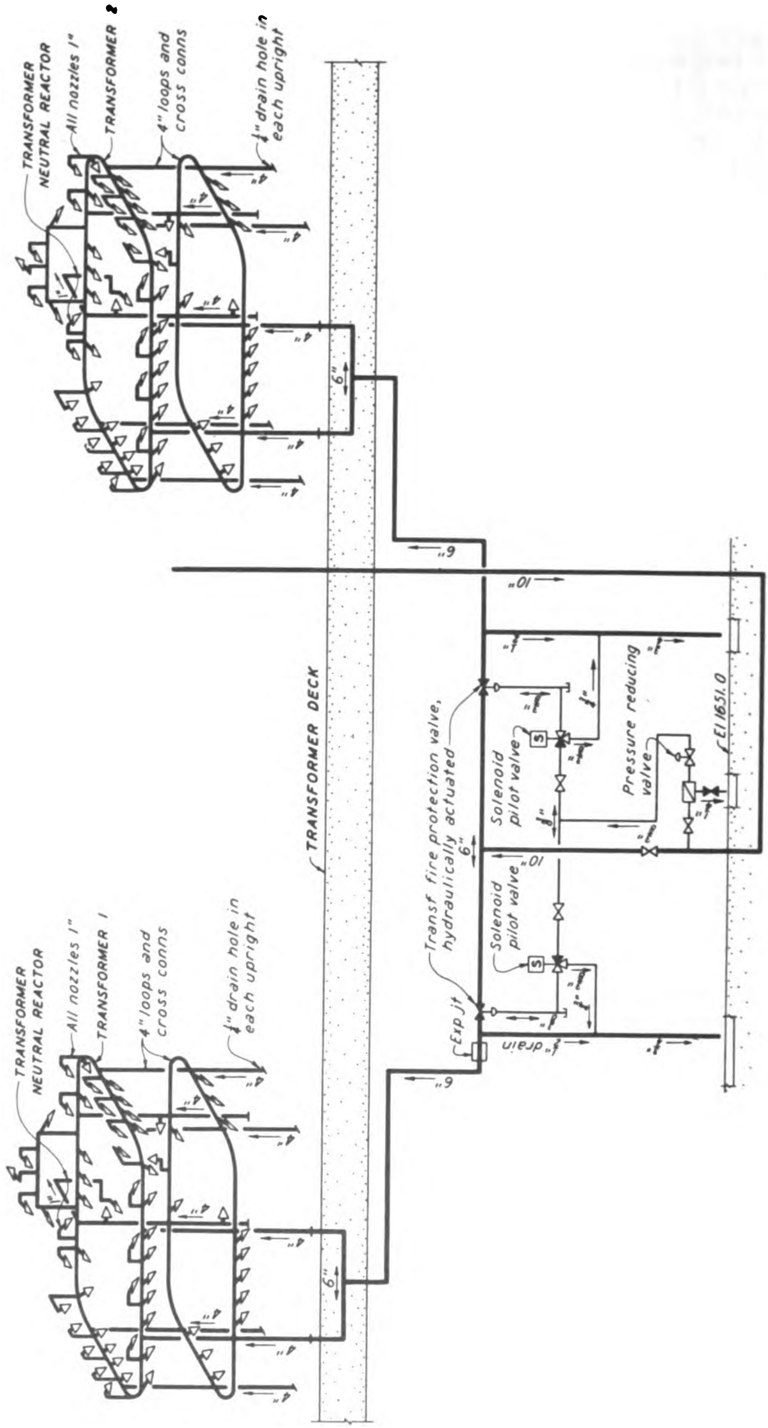

FIGURE 276.—*Flow diagram of transformer automatic water spray fire protection system—Watauga.*

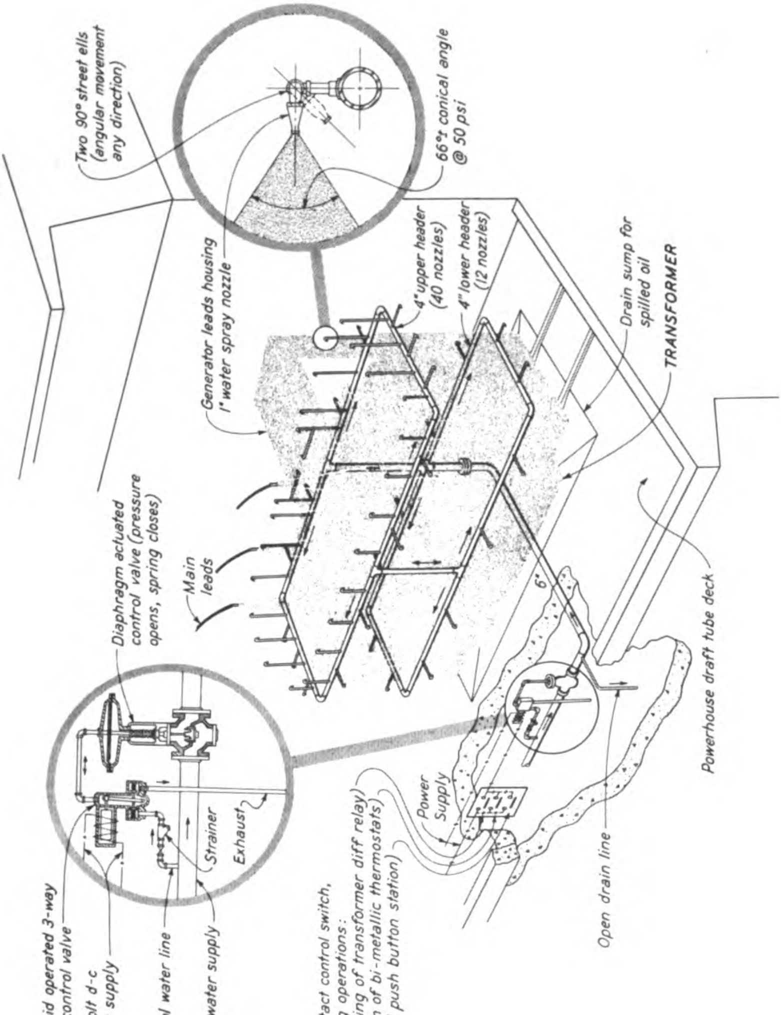

FIGURE 277.—*Schematic transformer water spray fire-protection system—Watauga.*

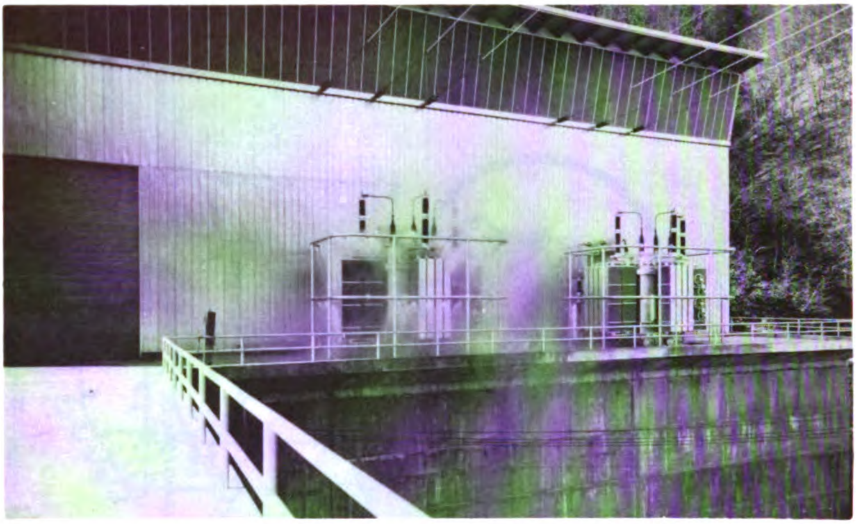

FIGURE 278.—*Transformer water spray fire-protection system in operation—Watauga.*

of water will be delivered to each system under minimum headwater conditions, or both transformers may be sprayed simultaneously with 2,400 gallons per minute delivered. Figure 278 shows the transformer fire-protection system with transformer No. 1 system in operation.

The control valves located in the powerhouse are normally closed, direct-acting, diaphragm-actuated valves of single-seated construction. The main valves shown in figure 279 are opened by a solenoid-operated, 3-way, pilot-control valve and closed by spring operation. The pilot-control solenoid which is wired into the 250-volt direct-current station battery system may be energized by any of the following:

1. Operation of the transformer differential relay which also shuts down the unit.
2. Operation of transformer thermostats.
3. Manual operation of sprinkler valve control switch auxiliary relay.

When the sprinkler valve opens, the auxiliary relay will energize the following equipment:

1. Annunciator.
2. Shut down unit.
3. Shut down the generator air cooler proportioning valve to 20 percent of its design capacity and disconnect it from its normal control.
4. Stop transformer blowers.

The sprinkler is shut off by turning the handle of the control switch auxiliary relay back to normal position.

Open drain lines near the outlet from the main valves drain the exterior portions of the system to prevent freezing.

Fort Patrick Henry project.—One 3-phase main transformer serves the two generating units at this remote-controlled station. The oil-insulated transformer, rated at 36,000 kilowatt-amperes, self-cooled, or 48,000 kilovolt-amperes, forced-air-cooled, and 13.8/69 kilovolts, is located in the transformer yard near the control bay of the powerhouse. An automatic fixed-spray fire-protection system is provided,

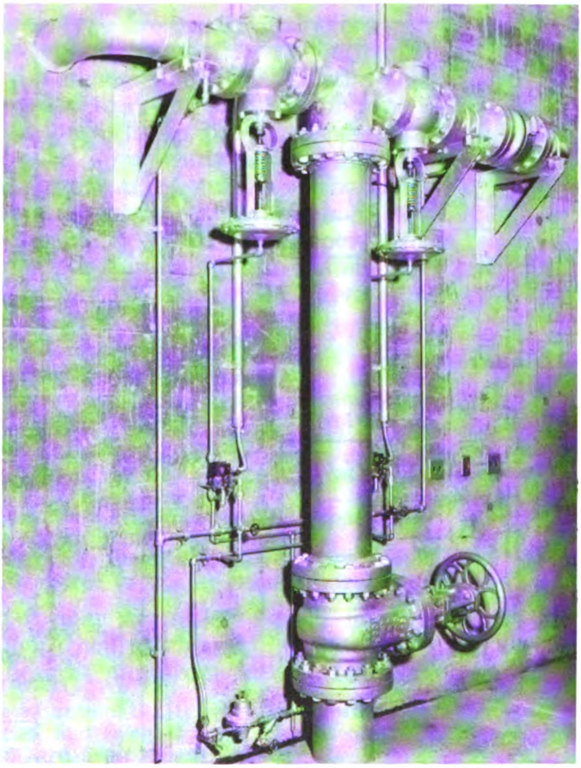

FIGURE 279.—*Automatic control valves for transformer fire protection—Watauga.*

including protective coverage for the station service transformer and neutral reactor. A flow diagram of the fire-protection system is shown in plate 37, page 556.

The 150-gallon-per-minute fire and service pump in the powerhouse supplies raw water from an intake in the forebay to an underground 25,000-gallon storage tank located on a hill near the powerhouse, with float switch control to maintain the full capacity. For transformer fire protection or use of the switchyard fire hydrants or powerhouse fire hose, a fire booster pump rated at 600 gallons per minute at a total dynamic head of 90 feet is provided which draws water from a 6-inch main from the storage tank and discharges into the fire and service piping system. A check valve bypass at the booster pump provides normal gravity flow to service outlets in the powerhouse.

The transformer fixed-spray fire-protection system is supplied from a 6-inch, hydraulically actuated, piston-check valve with solenoid-operated pilot valve located in the vestibule of the control bay in the powerhouse. A typical valve of this type is shown in figure 280. A valve disc is held closed by a water-pressure-operated piston acting through a roller and a cam on the disc. The water for operating the piston is controlled by a 3-way solenoid-operated valve which in turn is actuated by thermostats and test push buttons. In the normal closed position of the main valve the deenergized 3-way

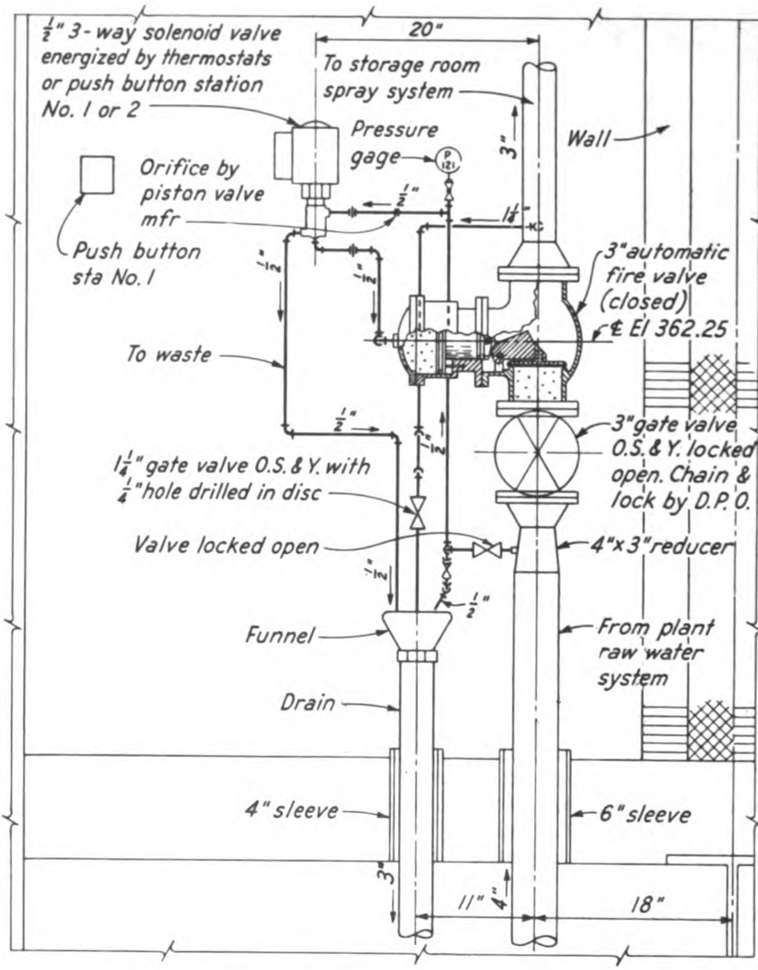

FIGURE 280.—*Typical check-type control valve for fire protection.*

solenoid valve connects main line water pressure to the piston of the main valve keeping it in the closed position.

In case of a fire, the solenoid valve is energized, closing off control water pressure to the main valve piston and opening the cylinder to waste which permits the disc of the main valve to open and provide full flow of water to the fire-protection system. These valves have been found to close consistently tight and prevent leakage which usually occurs in control valves of other types after a few operations. This type of valve being of the check valve principle offers little resistance to the water flow as opposed to the globe-type design which has a considerable pressure drop. This is an important factor in fire-protection systems where adequate pressure is paramount.

Considerable trouble has been experienced with water hammer during opening and closing cycles of globe-type control valves due to turbulence and the required speed of operation. The piston-

operated check-type fire control valve is free of turbulence and water hammer and operates smoothly on both opening and closing.

A small drain near the outlet of the transformer fire-protection valve is provided to drain the exterior pipe system to prevent freezing. A pipe loop system provides even distribution for a total of fifty-four 1-inch spray nozzles, including 8 nozzles at the station service transformer and 4 nozzles at the neutral reactor. The nozzles discharge at a flowing pressure of about 24 pounds per square inch to deliver approximately 13 gallons per minute per nozzle or a total of 720 gallons per minute for the system.

The transformer fire-protection valve auxiliary relay is operated by the following:

1. Transformer differential relay.
2. Transformer thermostats.
3. Emergency manual switch near transformer.
4. Test switch located on main control board.

When the transformer fire-protection valve auxiliary relay operates, the following functions are performed:

1. Transformer fire-protection valve opens.
2. Fire booster pump starts.
3. Transformer blowers stop.
4. Annunciation sounds at Boone control building.

The transformer sprinkler system is shut off by the on-off-test switch on main control board.

The fire booster pump operates as follows:

1. Started automatically when transformer sprinkler system is turned on.
2. Started and stopped from manual control station located near pump for switchyard fire hydrant use.
3. Started manually for powerhouse fire hose use from push-button station located in control room. Stopped by operating on-off test switch on control board to "Off" position momentarily.
4. Stopped by low-pressure switch on suction of pump, indicating that storage tank is empty.

Water-fog systems

Fixed installations of fog-type transformer and oil circuit breaker fire-protection systems are now installed or proposed at the Pickwick, Ocoee No. 1, and Apalachia projects as follows:

Pickwick Landing project.—The 6 generating units at this power station are served by 6 banks of single-phase, oil-insulated transformers located on the transformer deck adjacent to the upstream wall of the powerhouse. A concrete fire wall separates each bank. Large rock-filled concrete sumps are provided beneath each piece of electrical equipment, with individual drains to the forebay to rapidly drain the sump in case of spilling or leakage.

The 6 transformer banks each contain 3 single-phase, 12,000-16,000-kilovolt-ampere transformers and an oil-filled neutral reactor. Each bank is individually rated at 36,000 kilovolt-amperes, self-cooled, or 48,000 kilovolt-amperes, forced-air-cooled, and 13.8/161 kilovolts.

The high-voltage leads from the main power transformers pass through oil circuit breakers on the generator room roof. Twelve 161-kilovolt oil circuit breakers are the 3-pole, outdoor, solenoid-

operated type, and are rated 161 kilovolts, 1,200 amperes, 60 cycles, with an interrupting capacity of 2,500,000 kilovolt-amperes each. Approximately 5,500 gallons of oil is contained in each breaker. These are installed over an individual concrete pit which is fireproofed and oilproofed to prevent leakage of oil into the powerhouse. The pits are individually drained to the forebay.

The fire-protection system, originally installed as a gravity-flow spray system, was altered to provide higher pressure water-fog protection. Figure 281 shows the new transformer bank No. 2 fire-protection system in operation.

A 25,000-gallon treated water storage tank located on the north embankment is supplied from the Pickwick Village treated water system through a 200-gallon-per-minute booster pump in the powerhouse. A fire booster pump rated at 1,200 gallons per minute and 275-foot total discharge head draws water from an 8-inch main from the tank and discharges into an 8-inch header located in the pipe gallery below the transformer deck which extends the length of the powerhouse. A check valve bypass at the fire booster pump provides gravity flow for other service connections from the system.

A 6-inch branch line from the header supplies water to the four breakers at units 1 and 2. Branch lines from the 6-inch manifold are equipped with 3- or 4-inch deluge valves of the solenoid-operated piston-check type which supply the dry pipe loop at each breaker. Each branch is drained by ¼-inch drain lines near the outlet from the deluge valves to prevent freezing. A strainer is also provided in each branch. Four 1½-inch fog nozzles are mounted in the pipe loop at each breaker, each nozzle delivering approximately 50 gallons per minute at a flowing pressure of 100 pounds per square inch at the nozzle, or a total of 200 gallons per minute per breaker.

The above deluge valves are located in the stair tower near the access to the powerhouse roof. All others supplying each of the 6 transformer banks and the remaining 8 oil circuit breakers on the

Figure 281.—*Fog system for transformer fire-protection in operation—Pickwick.*

powerhouse roof are located in the pipe gallery near the main header.

Eight 4-inch drained branch lines, each with a solenoid-operated piston-check valve and strainer, supply the 2½-inch pipe loops at each of the remaining oil circuit breakers. Four fog nozzles, same as those installed at units 1 and 2, are provided in each loop to deliver a total of 200 gallons per minute per breaker.

Transformer banks Nos. 1 and 2 are each supplied from a 6-inch branch line equipped with a solenoid-operated piston-check valve and small open drain. All flow to the fog nozzles is strained to eliminate scale or particles from the water which might clog the orifices in the nozzles. Four 1½-inch fog nozzles, rated at 50 gallons per minute at 100-pound-per-square-inch pressure, are mounted in headers above each of the three single-phase transformers and deliver a total of about 200 gallons per minute per transformer. In addition, two 1-inch fog nozzles, rated at 21 gallons per minute at 100-pound-per-square-inch pressure, are provided for coverage of the neutral reactor, and four 1-inch fog nozzles, same capacity as above, are provided for coverage of the station service transformers at each bank. The total flow requirement to either transformer bank 1 or 2 is approximately 726 gallons per minute.

Transformer banks 3 to 6, inclusive, are also supplied from 6-inch branch lines from the main header. A solenoid-operated piston-check valve, similar to that described for the Fort Patrick Henry system and shown in figure 280, and a small open drain is in each line. Strainers are installed near the nozzles. Four 4-inch branch lines are provided for even distribution of pressure to the pipe loops above the three single-phase transformers and neutral reactor at each bank. Two 1½-inch fog nozzles at the neutral reactor and four 1½-inch fog nozzles at each single-phase transformer, each rated at 50 gallons per minute at 100-pound-per-square-inch pressure, are provided to deliver a total of 700 gallons per minute per transformer bank for these four systems.

The over-all fire-protection system is designed to allow one transformer bank and any two oil circuit breaker fire-protection systems to be operated simultaneously.

The fire booster pump operates as follows:

1. Started automatically when any transformer or oil circuit breaker sprinkler system is turned on.
2. Started from manual test switch located near pump.
3. Started from two manual switches for fire hose use.
4. Stopped manually except that provision is made by means of a pressure switch to automatically stop the pump when storage tank water supply is depleted.

The transformer fire-protection valve auxiliary relay is operated by the following:

1. Transformer differential relay.
2. Transformer thermostats.
3. Emergency manual switch.

When transformer fire-protection valve auxiliary relay operates, the following functions are performed:

1. Transformer fire-protection valve opens.
2. Fire booster pump starts.
3. Transformer blowers stop.

4. Generator room supply fans stop (banks 4 and 6 only).
5. Electrical bay exhaust fan stops (banks 3 and 5 only).
6. Annunciation sounds in control room.

The transformer sprinkler system is shut off manually.

The oil circuit breaker fire-protection valve auxiliary relay is operated by the following:

1. Oil circuit breaker thermostats.
2. Emergency manual switch.

When oil circuit breaker fire-protection valve auxiliary relay operates, the following functions are performed:

1. Oil circuit breaker fire-protection valve opens.
2. Fire booster pump starts.
3. Annunciation sounds in control room.

The oil circuit breaker sprinkler system is shut off manually.

Ocoee No. 1 project.—The transformer fire-protection system for this station provides high-pressure fog nozzle coverage for the 4 main power transformers serving the 5 hydroelectric generating units. The water-cooled, oil-insulated, 3-phase transformers are rated as follows:

Transformer No. 1—7,500 kilovolt-amperes, 120/66–2.276 kilovolts
Transformer No. 2—10,000 kilovolt-amperes, 120/66–2.276 kilovolts
Transformer No. 3—12,000 kilovolt-amperes, 120/66–6.828/2.276 kilovolts
Transformer No. 4—12,000 kilovolt-amperes, 120/66–6.828/2.276 kilovolts

The transformers are located adjacent to the switch building, with a trench at the building wall to carry spilled oil and water to the tailrace.

Two 8-inch raw water intakes from the forebay are utilized to supply the 10-inch suction line to a fire booster pump located in the basement of the powerhouse. A 10-inch twin strainer is provided in the suction line to the pump. The fire booster pump, rated at 1,400 gallons per minute and 235-foot total discharge head, discharges through a 10-inch motor-operated gate valve to the piping system which provides simultaneous coverage for all four transformers.

One branch line is mounted externally on the wall of the switch building and supplies six 1½-inch fog nozzles, rated at 100 gallons per minute at 100-pound-per-square-inch pressure, for coverage of the building side of transformers Nos. 1 to 3, inclusive. A second branch line consists of a header mounted in the switching structure which terminates in a 3-inch pipe loop at transformer No. 4. Two 1½-inch fog nozzles at transformers Nos. 1, 2, and 3 provide coverage on the side opposite the building, and four 1½-inch fog nozzles in the pipe loop provide coverage of transformer No. 4. These nozzles are rated at 50 gallons per minute at 100-pound-per-square-inch pressure, delivering approximately 300 gallons per minute of water to transformers Nos. 1, 2, and 3, and 200 gallons per minute to transformer No. 4.

Headwater pressure is maintained on the inlet to the motor-operated gate valve on the pump discharge, and a small open drain near the outlet from the valve is furnished to prevent freezing of exterior piping. The motor-operated gate valve, normally closed,

is opened, and the fire booster pump motor is started when the fire-protection system is energized by one of the following:

1. Transformer differential relay.
2. Transformer thermostats.
3. Push-button station at the pump.
4. Push-button station in corridor near office.

The fire-protection system is stopped by manual push-button control or by operation of a low-pressure switch on the pump suction to prevent operation of the pump through a closed valve in the suction line.

Two fire hose connections are also provided, one at each end of the building adjacent to the transformers, for manual application from hose lines.

Apalachia project.—The 2 generating units at this project are served by 2 main power transformers located in the transformer yard adjacent to the powerhouse. These 3-phase, oil-insulated transformers are rated at 36,000 kilovolt-amperes, self-cooled, or 48,000 kilovolt-amperes, forced-air-cooled, and 13.8/161 kilovolts.

This station is proposed to be converted for remote control operation, in which case an automatic fixed water fire-protection system for the transformers will be required. The proposed fire-protection system will provide high-pressure fog nozzle coverage for either transformer bank, consisting of the main power transformer, neutral reactor, and station service transformer.

The present yard hydrants are operated on reduced pressure from raw water intakes at the penstocks of both units. The minimum pressure available from headwater was found to be sufficient for fog nozzle operation, and the proposed design will provide a 6-inch connection on the strained raw water manifold utilizing full headwater pressure. Two 6-inch branch lines from this supply header will each contain a solenoid-operated piston-check valve, an additional Y-type strainer with smaller perforations, and a 3/8-inch open drain to prevent freezing of the exterior piping, the above equipment being located near unit 2 penstock in the basement of the powerhouse.

Each piping system at the transformer banks will consist of the 6-inch header with two 4-inch branch lines mounted above the transformers, using the switching structure for support of the 6-inch headers. Each 4-inch branch line will supply two 1½-inch fog nozzles rated at 100 gallons per minute at 100-pound-per-square-inch pressure and two 1½-inch fog nozzles rated at 50 gallons per minute at 100-pound-per-square-inch pressure, or a total flow of approximately 600 gallons per minute of water per bank. The ultimate arrangement will provide four 100-gallon-per-minute fog nozzles for each main transformer and two 50-gallon-per-minute fog nozzles each for the neutral reactor and station service transformer.

The electrically operated deluge valves controlling operation of the fire-protection system will be opened by either the transformer differential relay, transformer thermostats, or manual push-button control for testing.

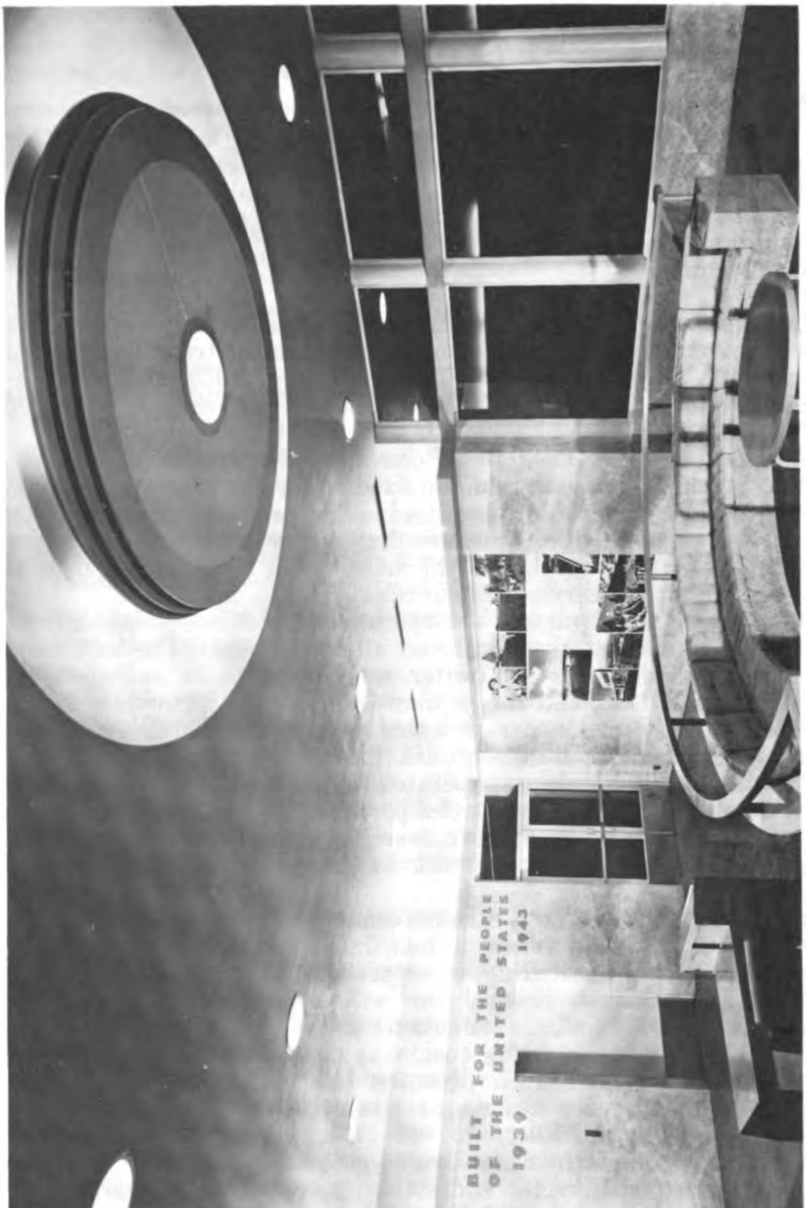

FIGURE 282.—*TVA-designed ceiling outlet fixture in Watts Bar control building.*

CHAPTER 14

HEATING, VENTILATING, AND AIR CONDITIONING

The need of heating, ventilating, and air conditioning is one that has to be evaluated and studied for each project in the preliminary phases of design. This need is dictated by the requirements for human comfort and efficiency and for the protection and operating efficiency of equipment and building structure. The engineer in charge of this phase of design, after determining basic needs and requirements, works very closely with the other design branches for determination of the method and schemes of providing the necessary services and to be certain sufficient space and facilities are available. This includes electrical and water services. To ensure that adequate space and facilities are maintained, this close liaison must be maintained throughout all design stages until the final issue of all design drawings of all branches.

Figure 282 shows a TVA-designed ceiling outlet fixture in the control building at Watts Bar.

Chapter 2, "The Projects," presents a brief description of the heating, ventilating, and air-conditioning systems installed at each of the 23 hydro plants discussed in that chapter. This chapter 14 explains in detail the design of these systems and presents reasons governing the selection of certain types of equipment and materials.

HEATING

Requirements

In all TVA hydro plant design, heating is accomplished by electricity due to its availability at a low cost and the simplicity and flexibility of installing electric heaters.

Heating is provided to all spaces where occupancy or removal of dampness and excessive chill requires an installation. In offices and similar spaces where continual occupancy is required by people who normally work with little physical exertion, heating is designed to maintain the conventional inside temperature of 72° F. with an outside design temperature in accordance with the recommendation of the American Society of Heating and Ventilating Engineers.

In larger rooms, such as shops, auxiliary equipment rooms, etc., the need for heating is not so critical as in the offices, and a lower inside design temperature is used. In some of these spaces, heating is supplemented by heat radiation from electrical equipment.

In the main generator rooms, because of very limited occupancy and heat absorbing quality of materials of construction, the power requirements for complete overall heating to comfort conditions are

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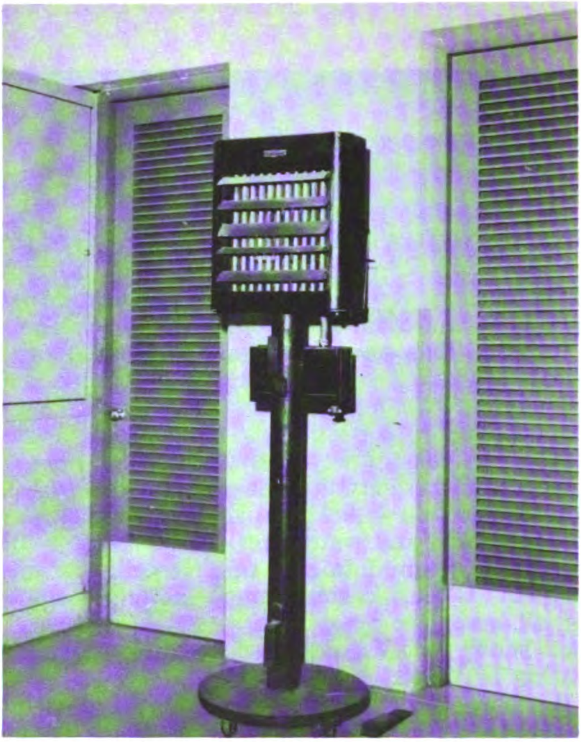


FIGURE 283.—*Typical 480-volt portable electric heater—Fontana.*

greater than can be justified. In these spaces, only spot heating is provided at locations or areas of frequent occupancy.

In addition to the permanently installed heaters, there are electric outlets for either 240-volt, single-phase, or 480-volt, 3-phase service throughout the powerhouse and service areas, and to which portable electric heaters (fig. 283) may be connected as desired.

Space heating

All space heating is done by one or more space heaters located within the space being heated. In all offices and similar spaces, not served by a central air-conditioning system that provides heating in addition to cooling, heating is by wall-mounted recessed, gravity convection, 240-volt, single-phase heaters (fig. 284). This type of heating is used because it is normally of low wattage and provides an even heat without objectionable high air temperatures. This type of heater is also highly desirable because it can be designed and constructed to exact tile or masonry openings and can be furnished in finishes and grille designs which harmonize with the architectural design of a plant. These heaters are controlled by a thermostat wired in series with the heating elements and are fed from a circuit in the lighting cabinet. Each heater has a built-in "On-Off" switch.

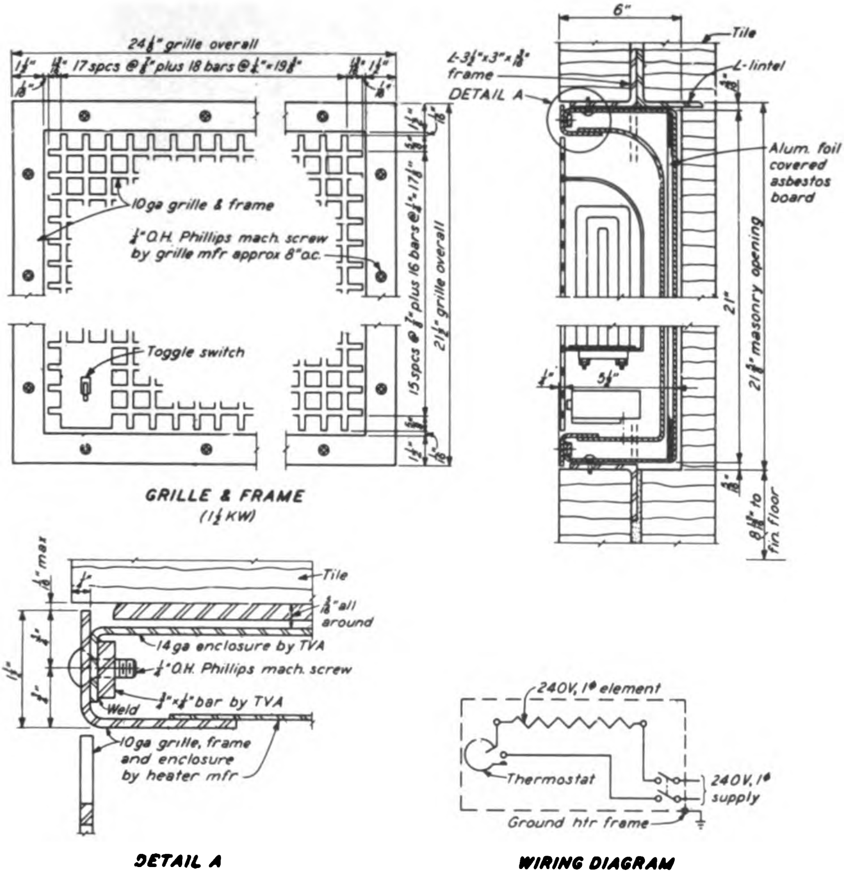


FIGURE 284.—*Typical recessed electric heater.*

In larger spaces and in spaces where architectural treatment is not so important, one or more fan-type, suspended, 480-volt, 3-phase electric heaters, such as shown in figure 285, are provided. This type of heater is used because of larger wattage available in the heater and better heat dispersion over a larger area. The number and location of heaters for each room are selected as required to give the best heater coverage and electric distribution. These space heaters are controlled by an on-off-auto switch in the space heated. In the "Auto" position control of the heater is through a thermostat in series with the 120-volt, single-phase holding coil of the heater contactor. In the "On" position the thermostat is bypassed and the heater is energized continually.

In the turbine room, spot heating is done by high-wattage, fan-type, 480-volt, 3-phase heaters, recessed into the masonry walls or mass concrete. Each heater is mounted behind a plate, installed flush with the interior wall. A large grille is placed in the lower part of the plate to permit air to the heater which discharges through an opening in the upper part of the plate. The control of these heaters is the same as described above for space heaters.

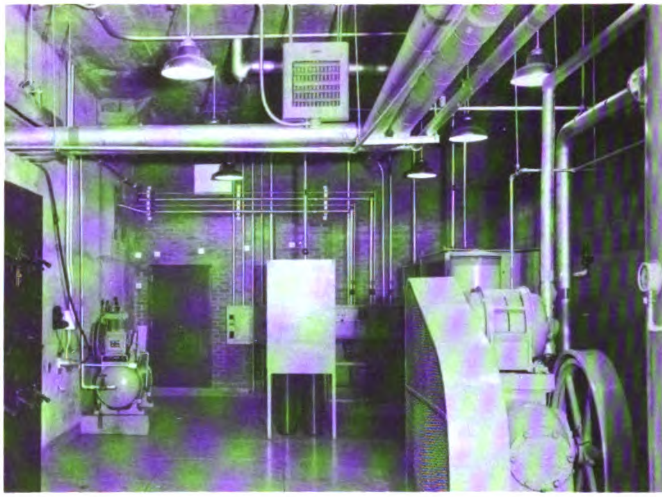


FIGURE 285.—*Typical fan-type electric heater—Fontana.*

Air duct systems

All spaces usually served by the central air-conditioning systems are supplied with heated air through the same air duct system that furnishes the chilled air. A typical heating and ventilating air flow diagram is shown in plate 39. The air quantity is reduced for the heating cycle as the normal cooling air quantity is not needed for the required heating and would present draft conditions which would be more critical during the heating season. The air quantity is reduced by slowing the speed of the supply fan either by a 2-speed, single-winding, or a variable-speed, wound-rotor motor.

The air is heated in the air-conditioning plenum by a duct-type air blast electric-heated, consisting of a structural frame and a number of finned-type strip heating elements. These elements are arranged in one or more 3-phase, 480-volt circuits of not more than 30 kilowatts to each circuit. This allows smaller loads to be cut-in at a given time on the electrical supply and also gives more desirable step control for various heating loads. Each circuit of multiple circuit heaters consists of heating strips so staggered in the frame that no two strips of the same circuit are adjacent.

Each circuit is controlled at a different temperature point. Heaters with three or less circuits have each circuit controlled from a separate thermostat mounted usually in the return duct from the spaces served. Each of these thermostats has settings that are staggered to provide the desired step control. On heaters with four or more circuits a single potentiometer-type, modulating thermostat is placed either in the space served or in a return duct from the space. This thermostat operates a programer which actuates mercury switches in sequence. Each mercury switch operates a contactor of one of the heater circuits, thus providing a full range of step control.

Each air duct heating system also has automatic humidity control through a direct-acting humidifier in the plenum. Each humidifier consists of an open pan of water, with the water level kept con-

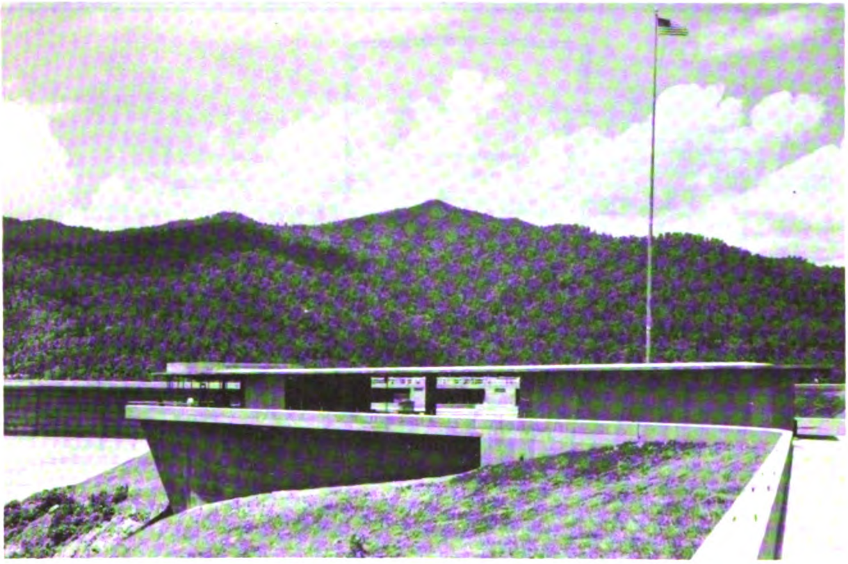


FIGURE 286.—*Radiantly heated visitors overlook building—Fontana.*

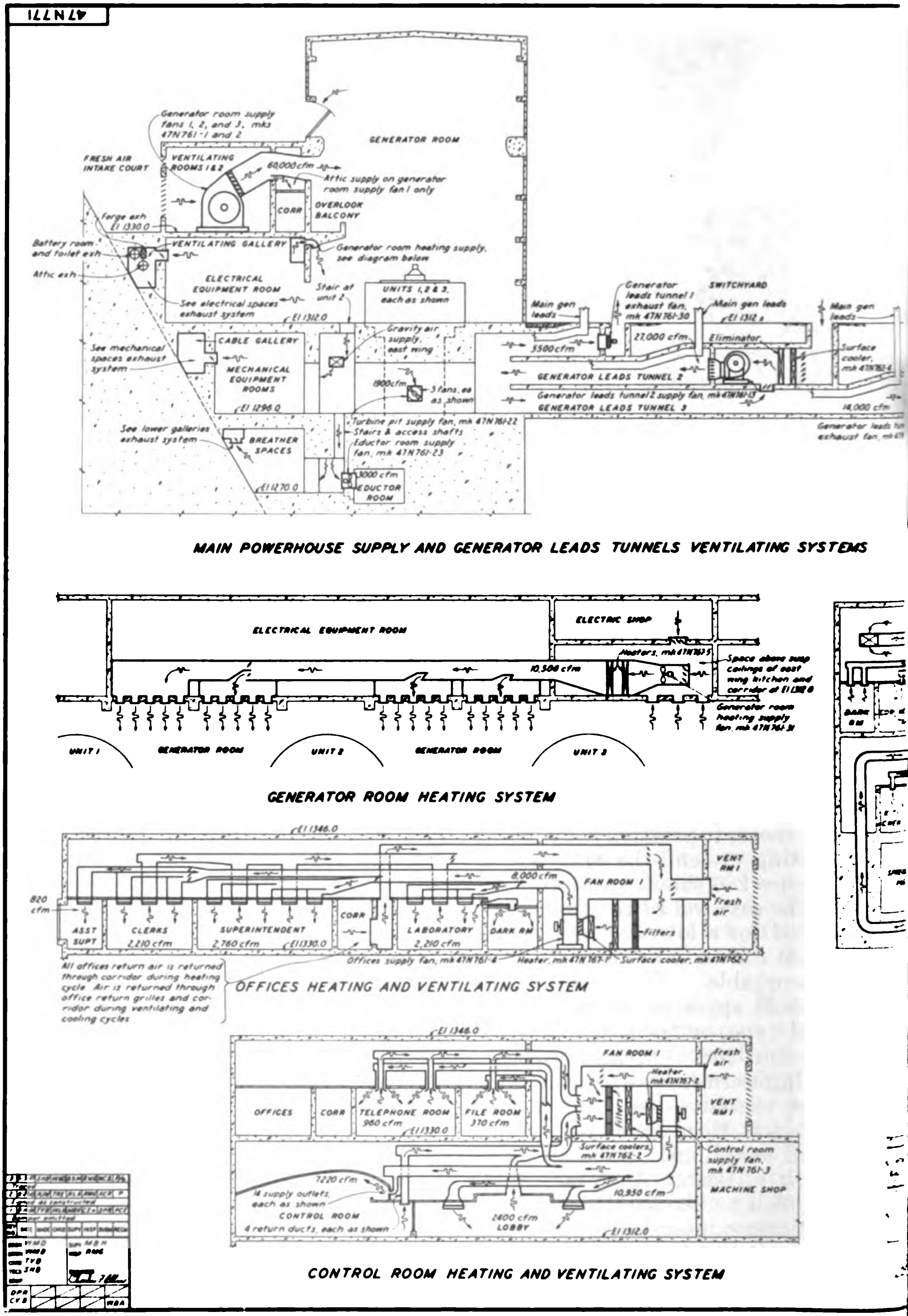
sistant by a float-type water feeder. An immersion heater, usually rated at 9 kilowatts, 480 volts, 3 phase, is placed in the open pan and controlled by a single-pole, single-throw humidistat located in the space being heated or in the return duct. The humidistat operates the contactor feeding the immersion heater. Water vapor is added to the moving air stream from the live steam emitting from the surface of the humidifier.

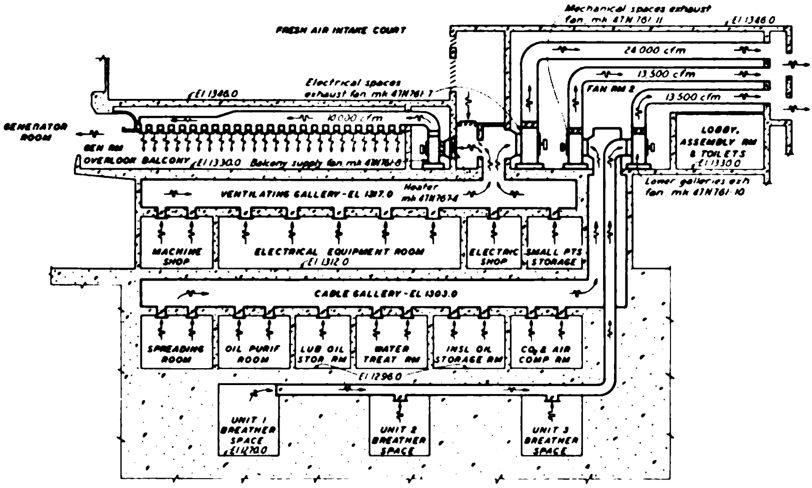
Radiant heating

At Fontana the lobby and toilet rooms of the visitors' building are heated primarily by a wrought-iron, floor-embedded radiant heating system, the only one of its kind in TVA's hydro projects. Figure 286 shows an exterior view of this building which is located at the east end of the dam. The architectural design of the building called for a low, flat roof and a very large glass window area which made conventional heating systems very undesirable and practically unworkable.

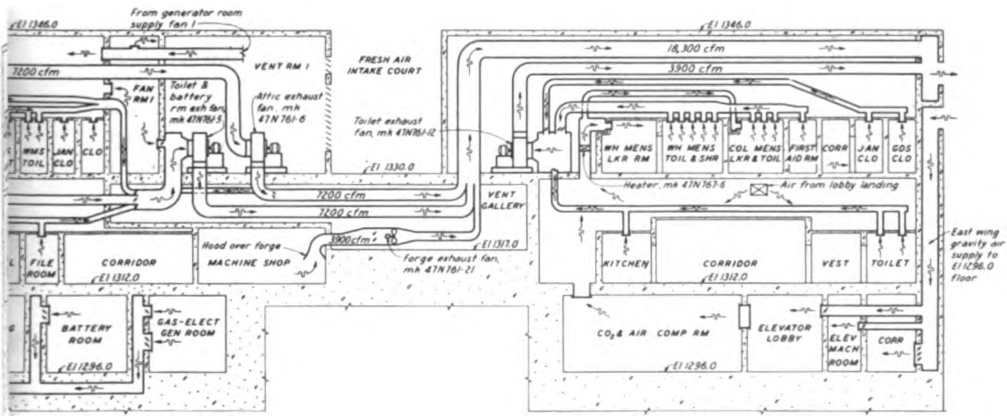
Each space is served by a pipe coil, either of the serpentine or grid type, embedded in a fill slab of the floor as shown in figures 287 and 288. On the top face of the structural slab a 2-inch layer of high-crushing-strength, foam-glass insulation was placed to prevent execssive loss of heat to unheated spaces below. Each pipe coil was then fabricated and the pipe lengths joined with socket weld couplings. Each coil was leveled and encased in a 3½-inch-thick fill slab. A ½-inch layer of sand was then spread over the fill slab and a final finish floor was applied.

A very interesting development occurred during the erection of the coils. After they had been embedded for about 2 years, water was noticed coming up from around the edges of the slabs and through cracks. The coils were leaking but the question was why

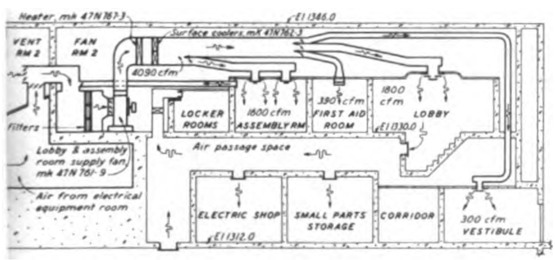

47N771
Generator room supply fans 1, 2, and 3, mks 47N761-1 and 2
GENERATOR ROOM
FRESH AIR INTAKE COURT
VENTILATING ROOMS 1 & 2
60,000 cfm
Attic supply on generator room supply fan 1 only
CORR
OVERLOOK BALCONY
Forge exh El 1330.0
Battery room and toilet exh
VENTILATING GALLERY
Generator room heating supply, see diagram below
Attic exh
ELECTRICAL EQUIPMENT ROOM
Stair at unit 2
UNITS 1, 2 & 3, each as shown
See electrical spaces exhaust system
El 1312.0
Main gen leads
Generator leads tunnel 1 exhaust fan, mk 47N761-30
SWITCHYARD
Main gen leads
El 1312
Main gen leads
Gravity air supply, east wing
27,000 cfm
Eliminator
Surface cooler
CABLE GALLERY
See mechanical spaces exhaust system
MECHANICAL EQUIPMENT ROOMS
3500 cfm
GENERATOR LEADS TUNNEL 2
1900 cfm
3 fans, ea as shown
Generator leads tunnel 2 supply fan
GENERATOR LEADS TUNNEL 3
14,000 cfm
El 1296.0
Turbine pit supply fan, mk 47N761-22
Stairs & access shafts
Eductor room supply fan, mk 47N761-23
Generator leads tunnel exhaust fan
See lower galleries exhaust system
BREATHER SPACES
3000 cfm
EDUCTOR ROOM
El 1270.0
MAIN POWERHOUSE SUPPLY AND GENERATOR LEADS TUNNELS VENTILATING SYSTEMS
ELECTRICAL EQUIPMENT ROOM
ELECTRIC SHOP
Heaters, mk 47N761-5
10,500 cfm
Space above susp ceilings of east wing kitchen and corridor at El 1312.0
Generator room heating supply fan, mk 47N761-31
UNIT 1
GENERATOR ROOM
UNIT 2
GENERATOR ROOM
UNIT 3
GENERATOR ROOM HEATING SYSTEM
El 1346.0
VENT RM 1
8,000 cfm
FAN ROOM 1
820 cfm
Fresh air
ASST SUPT
CLERKS 2,210 cfm
SUPERINTENDENT 2,760 cfm
El 1330.0
CORR
LABORATORY 2,210 cfm
DARK RM
Filters
Offices supply fan, mk 47N761-4
Heater, mk 47N761-7
Surface cooler, mk 47N762-1
All offices return air is returned through corridor during heating cycle. Air is returned through office return grilles and corridor during ventilating and cooling cycles
OFFICES HEATING AND VENTILATING SYSTEM
El 1346.0
FAN ROOM 1
Fresh air
Heater, mk 47N767-2
OFFICES
CORR
TELEPHONE ROOM 960 cfm
FILE ROOM 370 cfm
Filters
VENT RM 1
El 1330.0
Surface coolers, mk 47N762-2
Control room supply fan, mk 47N761-3
7220 cfm
10,950 cfm
MACHINE SHOP
14 supply outlets, each as shown
CONTROL ROOM
4 return ducts, each as shown
2400 cfm
LOBBY
El 1312.0
CONTROL ROOM HEATING AND VENTILATING SYSTEM



EQUIPMENT BAY HEATING AND VENTILATING SYSTEMS



TOILETS AND MISCELLANEOUS HEATING AND VENTILATING SYSTEMS



Y AND ASSEMBLY ROOM HEATING AND VENTILATING SYSTEM

Not to scale

POWERHOUSE

HEATING & VENTILATING AIR FLOW DIAGRAMS

FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
G. V. Davis	H. J. Petersen	George R. Rich

KNOXVILLE	9-25-43	10	M	4	47N771R3

PLATE 39

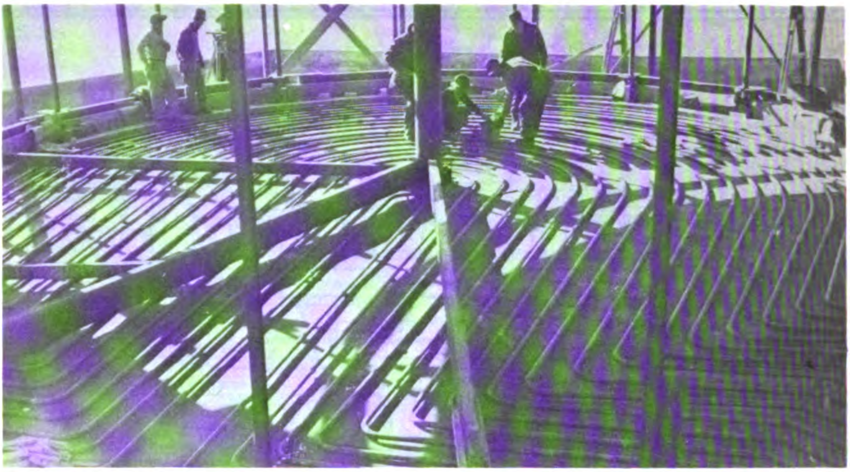


Figure 287.—*Grid type radiant heating coils—before embedment—in Fontana visitors building reception room.*

and how. There being no other choice one of the coils was removed, and on the bottom at various places along the pipe the metal was eaten away to the point of rupture or near rupture. A laboratory analysis showed this to be the result of electrolysis.

Further investigation, including a detailed study of construction photographs and discussion with the former concrete foreman, determined the cause of failure. Each coil was leveled during initial construction by double wedges placed as required. A grout mixture was applied beneath the pipe adjacent to the wedges to form a permanent support. The weather was extremely cold on the day in November when the grout was placed and one of the concrete men, without authorization, mixed into the grout a portion of calcium chloride to prevent it from freezing. Later, the encasing slab was poured using straight concrete with no additives. The pipe then was embedded in a slab in contact with dissimilar materials and provided a good path for current flow. The resulting galvanic cell slowly ate away the iron, causing pipe failure. All the pipe coils had to be removed, rebuilt, and replaced.

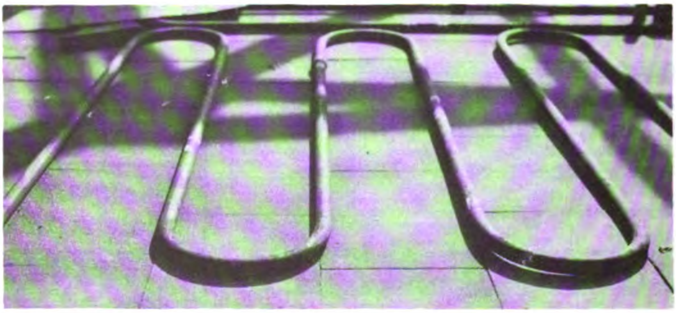


Figure 288.—*Serpentine type radiant heating coils—before embedment—in Fontana visitors building toilet room area.*

Water used in the coil system is heated in a tank supplied with 440-volt, 3-phase, 60-cycle immersion heaters. These heaters are controlled by thermostats set in steps and designed to maintain approximately 135° F. water at all times. Also, a high limit thermostat set at 180° F. interrupts all heating circuits on excessive heating.

Each heating coil is provided with a pump to circulate water. The heating water temperature to the coil varies and is controlled by a self-contained, 3-way mixing valve that automatically mixes hot water and return water in the correct proportions and in proper relation to outside air temperature. Each radiant heating water mixing valve has two sensitive elements—one in the outside air and the other in the delivered water side of the valve. The details of the water pumps, water heater, and control valves are shown in figure 289.

In each space a limit thermostat is placed to stop the pump when overheating occurs.

Reclaimed heating

Plant areas containing concentrations of heat producing electrical equipment are normally ventilated for the protection of the equipment and the comfort of the operators by exhausting the heated air to outside. At some plants, where structural conditions permit, the air thus heated is returned to powerhouse areas requiring heat. An example of a reclaimed heating system is found in the Fort Loudoun powerhouse. The main generator leads are cooled by forced air circulation and the air leaving the leads housing is warmed and normally discharged to outdoors in the switchyard. During the heating season this discharge air is returned to the powerhouse. The reclaimed heat thus furnished is usually not enough to completely heat the areas supplied, but supplements the regular installed heating facilities.

VENTILATING

Forced ventilation is provided in all spaces where there is a need either for human comfort and efficiency or for protection of equipment from heat or moisture. Wherever possible all ventilation fans and equipment are grouped into a common central room for ease of maintenance and conservation of floor space. A typical ventilating fan room is shown in figure 290.

Heat removal

In all spaces where there is a buildup of heat due to solar load, electrical equipment, or other source, a fan-powered exhaust system prevents excessive ambient temperatures. Air quantities required to provide satisfactory ventilation are computed, using the following formula:

$$\text{Cfm} = \frac{\text{Btu of heat to be removed}}{\begin{array}{l}0.0175 \times \text{temperature rise in degrees F. above}\\ \text{outside temperature}\end{array}}$$

The British thermal units to be removed is the sum of all heat-producing loads. A temperature rise of 5° to 10° F. is usually used, based on the nature of occupancy and critical need of keeping a satisfactory ambient for the equipment.

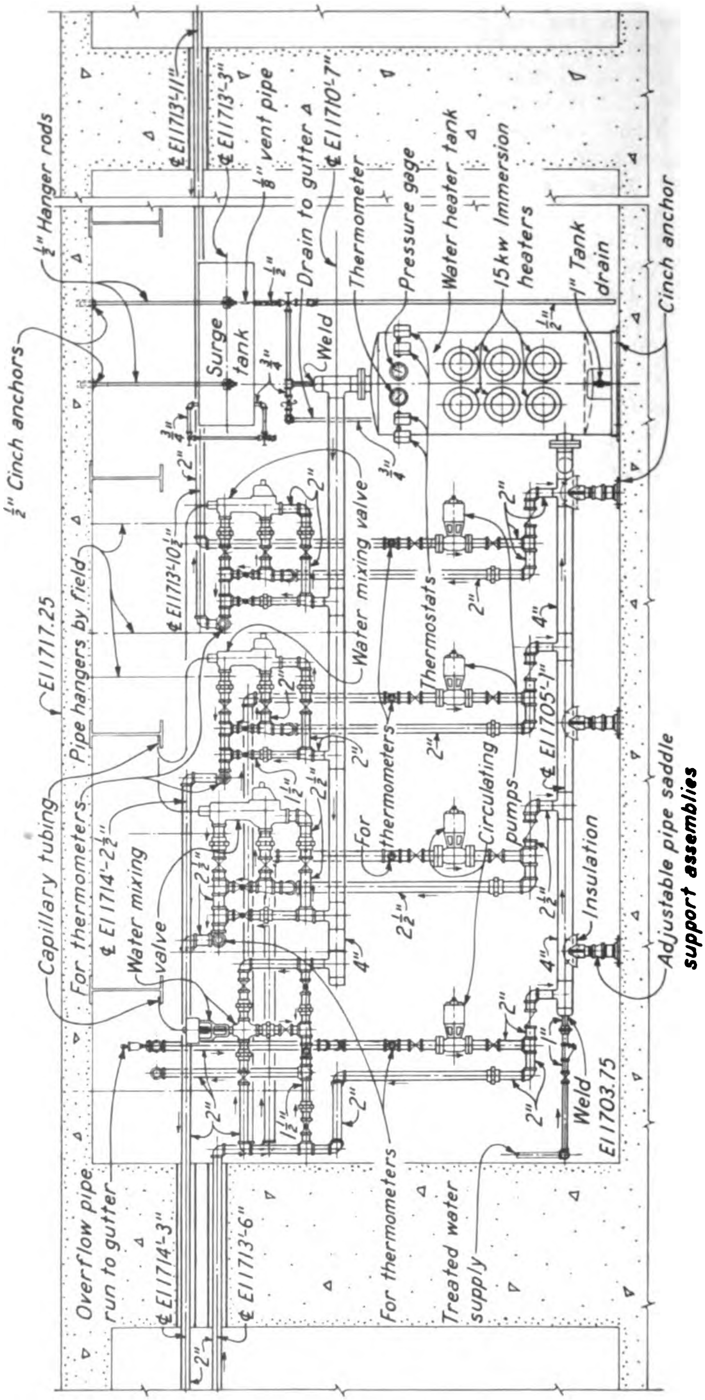


Figure 289.—*Electric water heater, pumps, and control valves of radiant heating system in Fontana visitors building.*

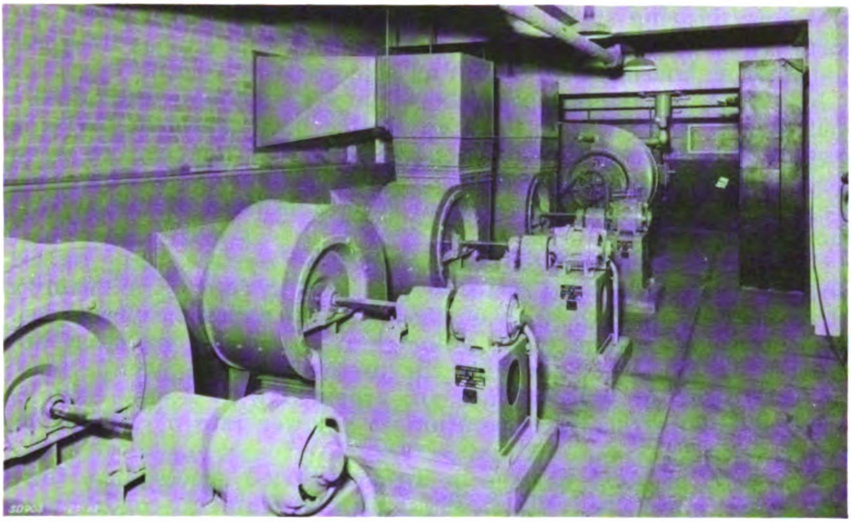


FIGURE 290.—*Typical ventilating fan room—Fort Loudoun.*

Air is exhausted, wherever possible, at the point of highest concentration of heat, using hoods if necessary. Air is generally induced into the space from the fan suction through openings at locations giving the best sweep of inlet across the space being served.

Moisture removal

In some spaces, especially low galleries and penstock valve rooms beneath the lake level, condensation on pipes and electrical equipment presents a problem and hazard. In the galleries, sufficient drying is usually accomplished by the use of 20-kilowatt, portable, fan-type, electric heaters placed so as to blow down the galleries.

In the penstock valve rooms located beneath the lake, such as at South Holston, a separate ventilation system supplies air that is dehumidified and heated. The dehumidification is accomplished by passing the air over a standard finned-type cooling coil, through which lake water is circulated. The lake water temperature is usually well below the dew point of incoming air so that dehumidification occurs. Heating is accomplished by a duct-type blast heater which raises the temperature of the incoming air to increase its moisture-carrying capacity per cubic foot. This relatively dry air passes through the valve room, picking up moisture, and then is discharged to waste.

Fume and odor removal

In all areas where obnoxious or dangerous fumes or odors exist, ventilation is provided to remove them and to provide a source of supply of fresh air at all times.

In battery rooms where battery charging gives off weak sulphuric acid fumes which would be harmful to human occupancy and would be corrosive if allowed to concentrate, air is exhausted in ducts made

of copper bearing steel, aluminum, or stainless steel, to lessen the corrosive effect of the gas. The fan handling this air has its wheel and interior housing coated with an acid resisting coating.

All forges in the machine shops have a separate, individually controlled exhaust system. An adjustable hood is placed over the forge which can be lowered to a point just above the coal bed when the forge is in operation and can be moved up, out of the way, when the forge is shut down. A typical adjustable hood of this type is shown in figure 291.

All toilets are ventilated by a forced-air system. Figure 292 illustrates a typical toilet ventilation exhaust system. The quantity of air is based on 45 to 60 air changes. TVA's experience has shown that lower air change rates, although recommended by other approved standards, do not give the desired removal at all times. In most cases the exhaust fans are provided with 2-speed, single-winding motors to allow operation at a lower rate of air change when desired.

The toilet exhaust systems in air-conditioned spaces have their fan motor interlocked electrically with the main air-conditioning supply fan, as fresh air makeup for the overall air-conditioning system is induced by the exhaust to the toilet exhaust system.

FIGURE 291.—*Adjustable hood over machine shop forge—Fontana.*

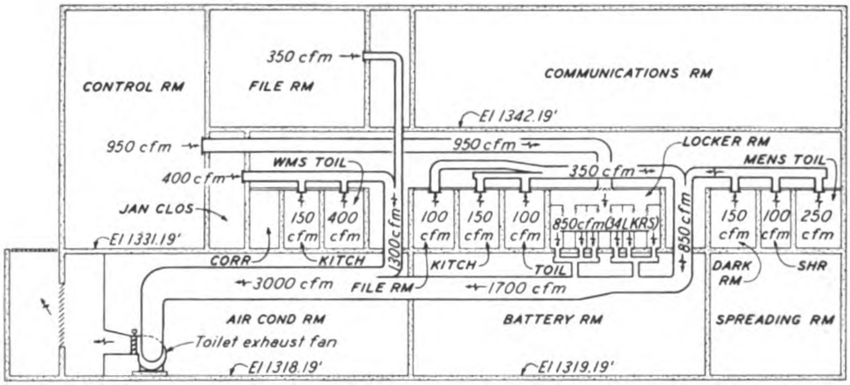


FIGURE 292.—*Typical toilet room ventilation exhaust system.*

AIR CONDITIONING

Requirements

Air conditioning is provided for either comfort and efficiency of personnel or protection of equipment.

The communications room, which contains all the electrical equipment required at each plant for communication facilities, has air conditioning primarily designed for the maintaining of low ambient temperature and a dust-free atmosphere which is essential to efficient operation and long life of the equipment. No consideration is given for human comfort, as this space has no normal occupancy. The offices, public reception spaces, and the control room areas are each served by separate air-cooling and supply systems. The nature of the load and exposure for each of these systems differs from the other two which makes separate control desirable. Cooling is ordinarily accomplished in each system by the circulation of chilled water through standard finned-type cooling coils. The chilled water is either cooled by mechanical refrigeration and stored in a large tank or is lake water drawn from the penstock at a temperature and in quantities sufficient for the cooling requirement.

The flow of water is controlled by pneumatic or electric, motor-operated, 3-way valves activated by a thermostat located in the space served or in the return duct from that space.

All air-conditioning equipment, including refrigerating equipment, air-handling equipment, and controls, is usually grouped in a compact centrally located space for ease of maintenance and conservation of space (fig. 293).

Design procedure

Before any actual computations are made on the air-conditioning load, certain basic assumptions are made and recorded. These assumptions establish the inside and outside air design temperatures which provide the relative humidity and dew point readings for both inside and outside. The basic inside condition is usually assumed to be 78° F. dry bulb and 64° F. wet bulb. The outside condition varies with the locality and is taken from the recommenda-

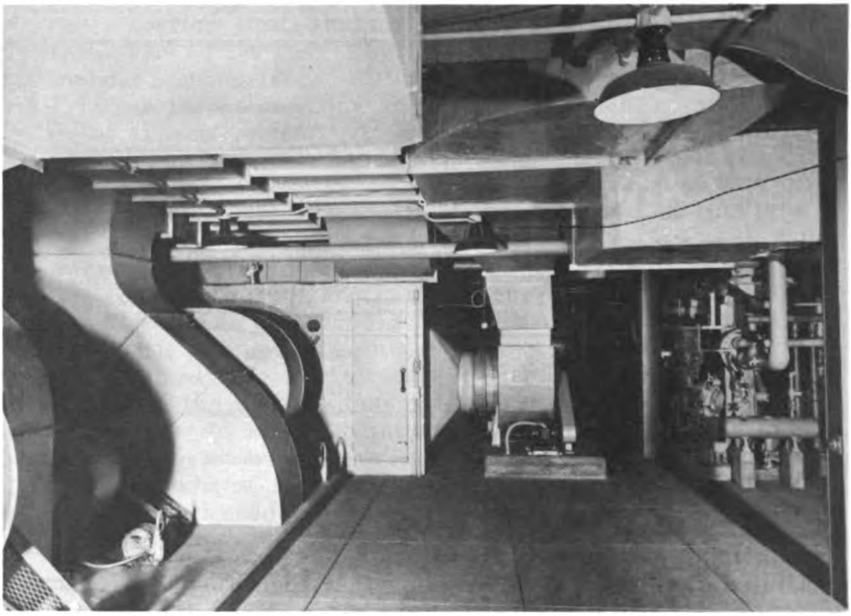


FIGURE 293.—*Air-conditioning equipment room—Boone.*

tions of the ASH&VE or from TVA experiences in that area. The assumed conditions give the sensible, latent, and total heat quantities from tables taken from the Guide of the ASH&VE.

The volume of the room air, given in cubic feet per pound, is next determined from a psychrometric chart. Infiltration and fresh air factors are next computed both for sensible heat per cubic foot of air and latent heat per cubic foot of air by the following formulas:

$$\text{Sensible heat per cubic foot of air} = \frac{\text{Sensible heat of outside air} - \text{Sensible heat of inside air}}{\text{Volume (cubic feet per pound of air)}}$$

$$\text{Latent heat per cubic foot of air} = \frac{\text{Latent heat of outside air} - \text{Latent heat of inside air}}{\text{Volume (cubic feet per pound of air)}}$$

All wall, roof, and floor sections are listed and "U" factor computed for each. Effective temperature differences are listed for each exposure of surface, for each section of wall as recommended by ASH&VE. Instantaneous solar load for each exposure of glass is also recorded.

Each room or space load is then computed using values of coefficients and temperature differences recorded above and measured areas of each type of conducting surface. The load due to infiltration, lights, electrical equipment, and occupants is also computed for each space. The sum of these individual loads is next obtained both as sensible and latent. Each space to be air conditioned is computed in this manner.

The supply air temperature to be carried in the duct is then selected. A supply air of 63 degrees Fahrenheit is preferred for small areas or for low ceilings; however, 60 degrees Fahrenheit is permitted for these spaces and is preferred for large rooms, giving a saving in duct size and air quantity.

The cubic feet of air per minute to be supplied to each space is then computed using the following formula:

$$\text{Cfm} = \frac{\text{Btu sensible heat} \times \text{cubic feet per pound of air at supply temperature}}{60 \times \text{specific heat of air} \times \text{temperature difference in degrees F. (room air—supply air)}}$$

Each system is then summarized by a tabulation of spaces together with their sensible and latent heat loads and air quantities. The sums of these spaces then give the total internal loads and air to be supplied.

Cooling coil designed conditions are next computed. Air entering the coil is computed as a mixture of return and fresh air. The fresh air quantity is that which is required to make up for air exhausted from the air-conditioned space to toilet or other exhaust systems. A minimum of 15 percent fresh air is always used. Air leaving the coil is next computed as is required to provide sufficient cooling for the internal load of the space.

Chilled water quantity in gallons per minute for each air supply system is next computed using the formula:

$$\text{Gpm} = \frac{\text{Total load in Btu}}{500 \times \text{temperature rise of water in degrees F.}}$$

A temperature rise of 10° F. is used in computing chilled water requirements.

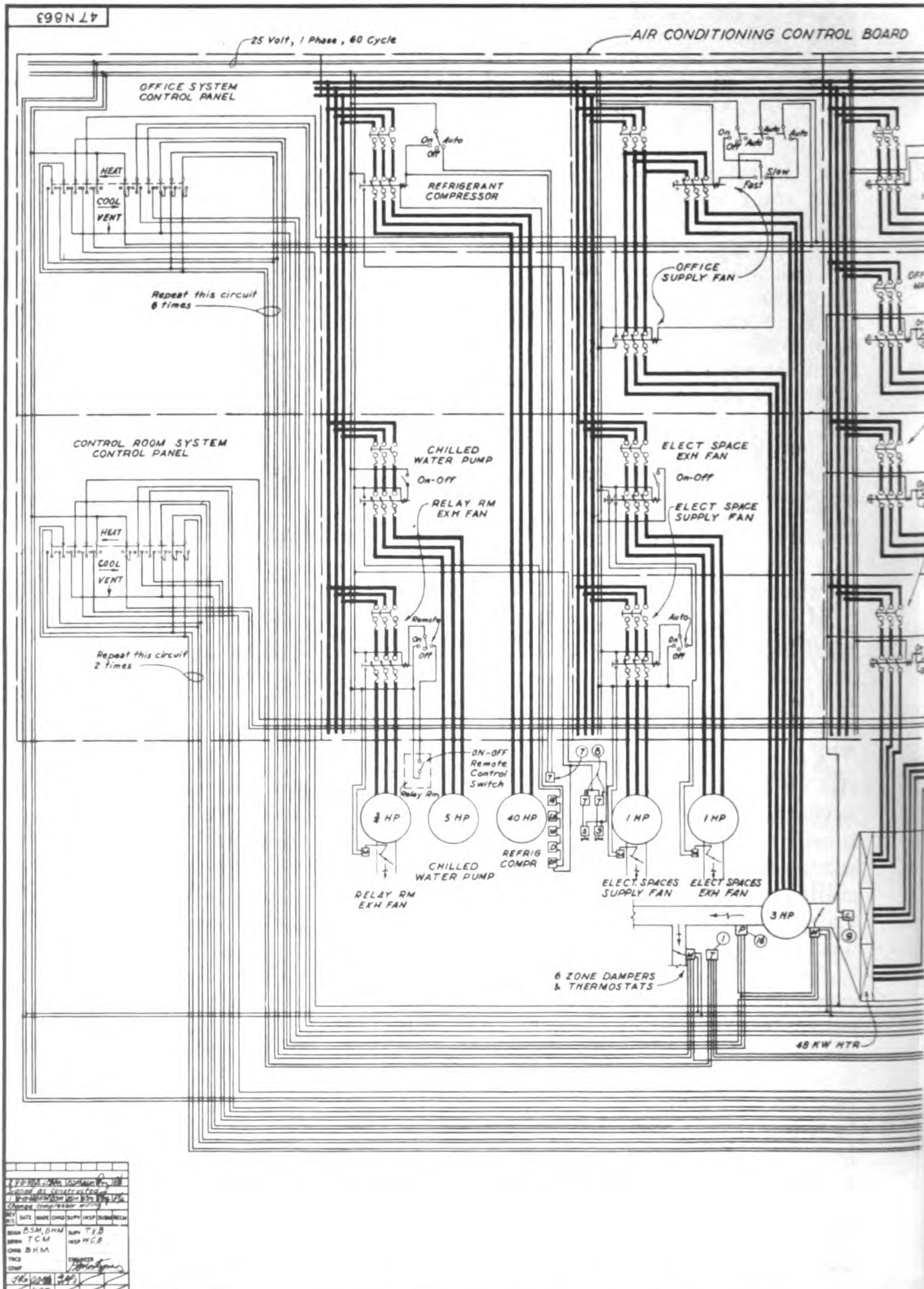
If mechanical refrigeration is used the tons of refrigeration is found by using the following formula:

$$\text{Tons of refrigeration} = \frac{\text{Total gpm} \times 500 \times \text{temperature rise of water in degrees F.}}{12{,}000}$$

After the equipment has been sized and selected to do the cooling, the air-handling and distribution systems are then designed. Duct layout and sizing are done by the pressure-drop method. The most critical phase of this design is routing of ducts to miss other services and to fit into building limitations. Grilles, registers, and ceiling outlet fixtures are selected and sized to handle the air, provide necessary throw and distribution pattern, and to fit architectural and light patterns.

After the complete air-handling system has been designed, a computation is made of the pressure drop of the entire supply and return ductwork for each system. This provides a value of the static pressure to be used in specifying the fan to handle the air.

Another very important phase of air-conditioning design is the method and sequence of control and the selection of the devices to perform this control. During the latter phase of the physical design a control diagram is prepared. A typical diagram of this type (plate 40) is referred to in the operating instructions included in appendix E. This is not a schematic, wiring, or electrical connection diagram, but it is a special diagram intended to show primarily sequence and method of control for the entire system, planned principally for the benefit of the mechanical operators of the system.



47N863
25 Volt, 1 Phase, 60 Cycle
AIR CONDITIONING CONTROL BOARD
OFFICE SYSTEM CONTROL PANEL
HEAT
COOL
VENT
Repeat this circuit 6 times
On
Auto
Off
REFRIGERANT COMPRESSOR
Slow
Fast
OFFICE SUPPLY FAN
CONTROL ROOM SYSTEM CONTROL PANEL
CHILLED WATER PUMP
On-Off
RELAY RM EXH FAN
ELECT SPACE EXH FAN
ELECT SPACE SUPPLY FAN
Repeat this circuit 2 times
Remote
ON-OFF Remote Control Switch
Relay Rm
1/4 HP
5 HP
40 HP
1 HP
1 HP
3 HP
CHILLED WATER PUMP
REFRIG COMPR
RELAY RM EXH FAN
ELECT. SPACES SUPPLY FAN
ELECT. SPACES EXH FAN
6 ZONE DAMPERS & THERMOSTATS
48 KW HTR
Change compressor wiring
DSGN B.S.M., D.H.M.
DRWN T.C.M.
CHKD B.H.M.
SUPV T.V.B.
INSP W.C.B.

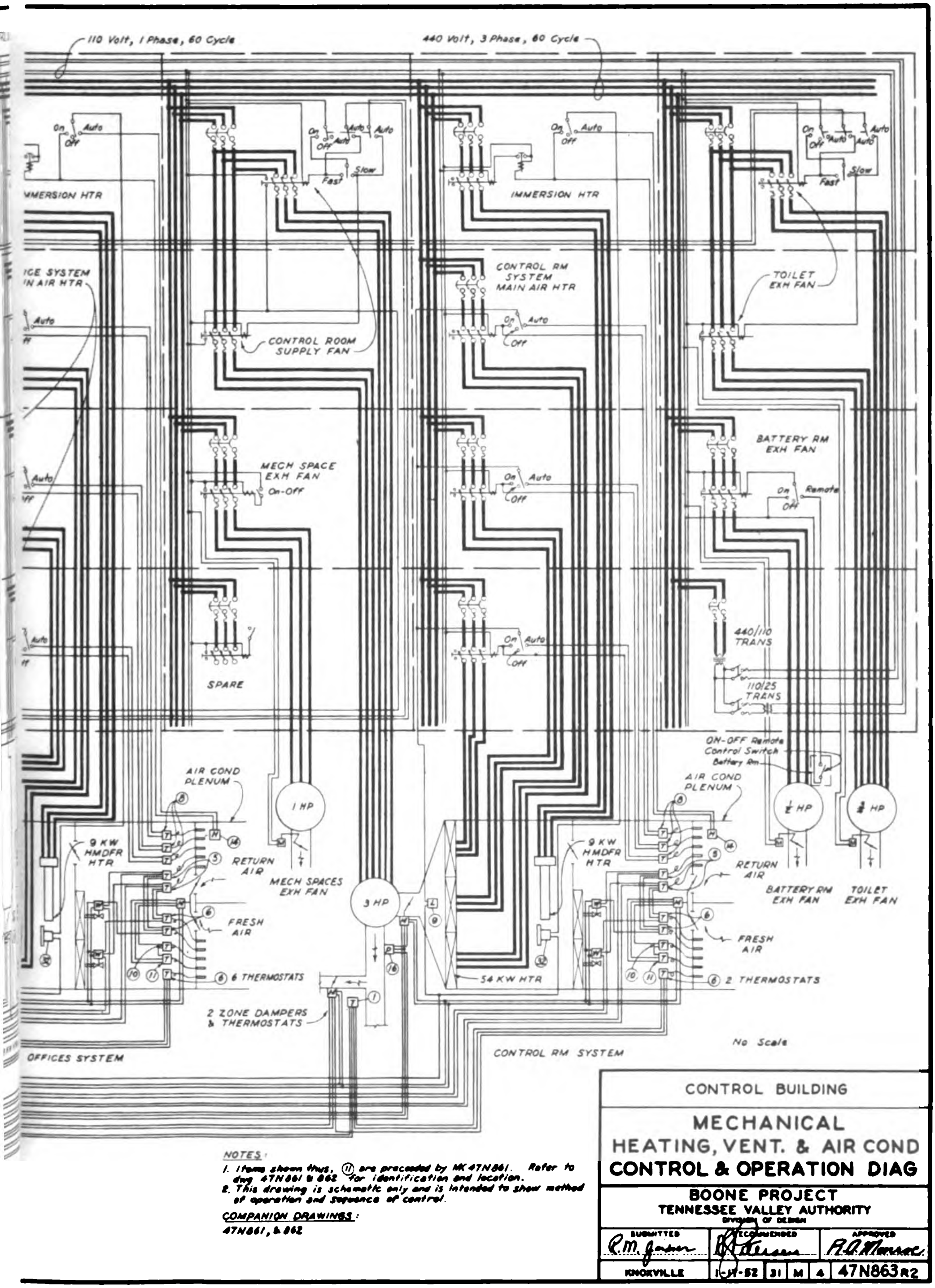

110 Volt, 1 Phase, 60 Cycle
440 Volt, 3 Phase, 60 Cycle
IMMERSION HTR
CONTROL ROOM SUPPLY FAN
CONTROL RM SYSTEM MAIN AIR HTR
TOILET EXH FAN
MECH SPACE EXH FAN
On-Off
BATTERY RM EXH FAN
SPARE
440/110 TRANS
110/25 TRANS
ON-OFF Remote Control Switch Battery Rm
AIR COND PLENUM
1 HP
3 HP
9 KW HMDFR HTR
RETURN AIR
MECH SPACES EXH FAN
FRESH AIR
6 THERMOSTATS
2 THERMOSTATS
2 ZONE DAMPERS & THERMOSTATS
54 KW HTR
BATTERY RM EXH FAN
TOILET EXH FAN
OFFICES SYSTEM
CONTROL RM SYSTEM
No Scale
NOTES:
1. Items shown thus, (11) are preceded by MK 47N861. Refer to dwg 47N861 & 862 for identification and location.
2. This drawing is schematic only and is intended to show method of operation and sequence of control.
COMPANION DRAWINGS:
47N861, & 862
CONTROL BUILDING
MECHANICAL
HEATING, VENT. & AIR COND
CONTROL & OPERATION DIAG
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
47N863 R2

PLATE 40

Chilled water systems

At most of the low head hydro plants water to provide cooling effect to the air-conditioning system is chilled by mechanical refrigeration. Equipment for this type of system is shown in figure 294. A schematic flow diagram of such a system is presented in figure 295. The water is circulated by a centrifugal pump, running continuously, which pumps the chilled water through a pipe distribution system to the control valve at each coil. This control valve is a three-way type that permits the water to go through the coil or to be bypassed directly into the return line. This prevents a shutoff head from ever occurring on the pump. The water leaving the valves or coils is conveyed by another pipe system to the chiller, which is the evaporator of the refrigeration system. Here heat is extracted from the water by the expansion and evaporation of the refrigerant. This lowers the temperature of the water leaving. The evaporator temperature is always maintained at 35° F. or above to protect against the freezing of tubes. The chilled water is discharged into a large storage tank, to which is attached the chilled water pump suction. The control of the refrigerating equipment is from the storage tank where thermostats are immersed and set to maintain 44° to 45° F. water at all times.

Lake water systems

At high head hydro plants where deep lakes are impounded, the water to the penstocks is taken at a considerable depth below the surface. The temperature of this water is sufficiently low at all times to make it usable for air conditioning. It is interesting to note that usually the minimum water temperature occurs during May and the maximum during October. The water pressure is sufficient for all piping and coil losses so no pump is necessary to maintain flow. The water is conveyed to the various air-conditioning systems

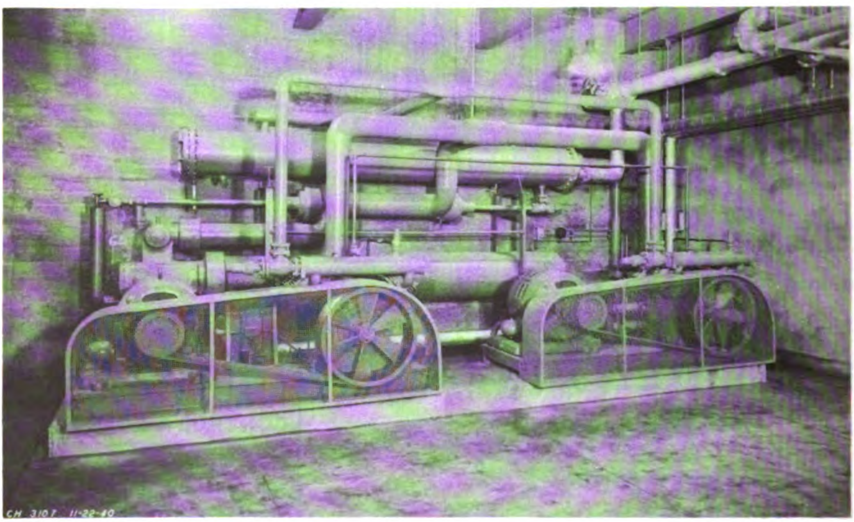


FIGURE 294.—*Water chilling equipment showing refrigerating compressor in foreground with condenser, heat exchanger, and water cooler at rear—Chickamauga.*

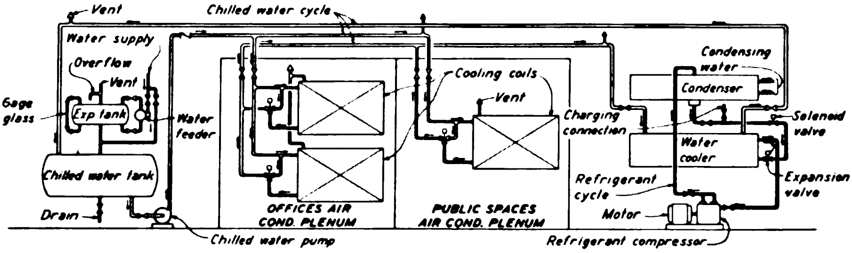


FIGURE 295.—*Schematic diagram of chilled water air-conditioning system.*

through a pipe distribution system and the flow is controlled by two-way pneumatic or electric motor control valves activated by thermostats located in the spaces served or in the return ducts. The water is then discharged to waste. A typical schematic diagram of this type of system is shown in figure 296.

At Cherokee and Douglas Dams, where large drawdowns in the summer months lower the lake elevation so that the penstock water originates nearer to the surface and is too warm for adequate cooling, an auxiliary mechanical refrigeration system is provided to bypass the lake water and do all the cooling from a central chilled water storage tank.

Direct expansion systems

At isolated areas, too remote or too small to be served from a central chilled water system, direct expansion systems are provided. The air is cooled by a standard finned-type coil which is the evaporator for the refrigeration cycle. A schematic diagram of this type of system is shown in figure 297. These systems in small sizes are purchased as standard floor-mounted, water-cooled packaged air-conditioning units. In larger sizes or in cases where standard units do not have enough surface for the cooling load, built-up systems are used with a separate condensing unit and plenum with cooling coil.

EQUIPMENT AND MATERIALS

Fans

TVA uses all three of the main types of fans—propeller, vaneaxial, and centrifugal. The designation of types is in accordance with definitions of the National Association of Fan Manufacturers. The type is selected on load characteristics, space available, noise evaluation, and service requirements.

Propeller fans are used generally where large quantities of air are handled with a very low static pressure requirement and where noise is not of consequence. Propeller fans are used to exhaust large areas with very little or no ductwork.

Vaneaxial and, in some cases, tubeaxial fans are used to handle large quantities of air at moderately high static pressures and at locations where the permissable noise level is high.

Where space permits and where noise is an important factor, TVA uses centrifugal fans, usually of the backward inclined-blade type. This type of fan runs at lower and quieter speeds than either

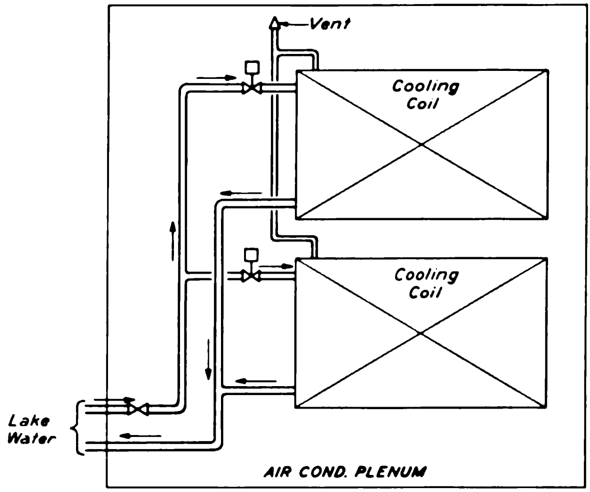


FIGURE 296.—*Schematic diagram of lake water air-conditioning system.*

the propeller or vaneaxial type. They have horsepower-capacity characteristics that prevent the overloading of the driving motor as dampers in the supply duct system are closed and opened. This type of fan has good efficiency, minimum of maintenance, and long life. In ordinary ventilation systems ball bearings are permitted in the fans; however, in air-conditioning supply systems sleeve bearing fans are used because of lower noise level.

All fans, regardless of type, are purchased with guaranteed ratings and are required to have certified rating curves taken from tests made in accordance with the latest applicable codes of the ASH&VE, National Association of Fan Manufacturers, or Propeller Fan Manufacturers' Association. Typical ventilating fan purchase specifications are given in appendix C, and a procurement drawing covering fans, filters, cooling coils, and electric heaters is shown in plate 41.

Roof ventilators

The generator room and miscellaneous spaces at the later hydro plants constructed by TVA are ventilated by electric-motor-driven roof ventilators of size, spacing, number, and capacity as required to provide the desired ventilation. A battery of roof ventilators of this type installed on the powerhouse roof at Hales Bar is shown in figure 298. In most cases propeller type fans have been satisfactory in these roof ventilators with a few centrifugal fan bladed units at isolated points. This type of ventilator provides a positive air change rate with the inlet at the point of maximum air temperature. There is very little installation cost involved and they can be controlled as desired by the operators.

Due to the special emphasis of architectural treatment on all TVA projects, only ventilators of a low height, capped with a round, mushroom canopy are used. All ventilators have an electric-motor-driven damper on the inlet which closes upon fan shutdown to prevent the infiltration of cold air, insects, or birds. Roof ventilator procurement specifications are included in appendix C.

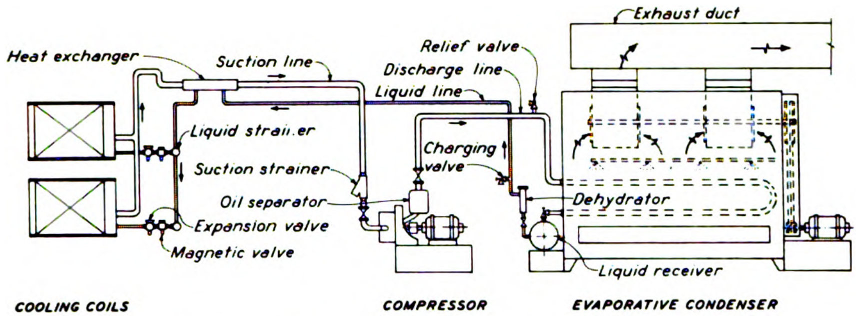


FIGURE 297.—*Schematic diagram of direct expansion air-conditioning system.*

Electric heaters

All heating is done with one or more heaters of these four general classifications—blast, fan-type unit, recessed gravity, or portable. The selection of the actual type is based on conditions at each space.

Blast heaters are used in supply air duct systems to one or more spaces. They provide an inexpensive installation to serve a large area, but present a problem of control when the air is supplied to several spaces of variable and different loading. This type of heater takes up very little additional space and is accessible for replacement or servicing; it is installed for 480-volt, 3-phase operation. On heaters of more than 20 kilowatts, usually two or more circuits are provided. These circuits are individually thermostatically controlled in steps to provide an even increase in heating. A limit thermostat adjacent to the heating elements on the leaving air side stops the entire heater on excessive temperature rise.

Fan-type unit heaters are used in all shops, service area, and spaces requiring fairly large quantities of heat which cannot be

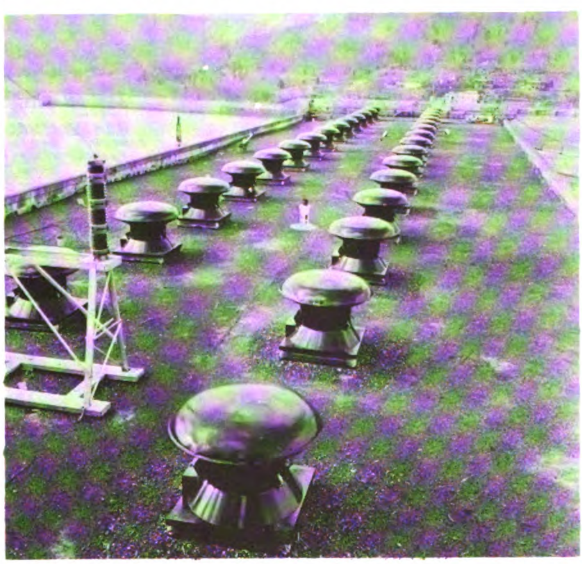


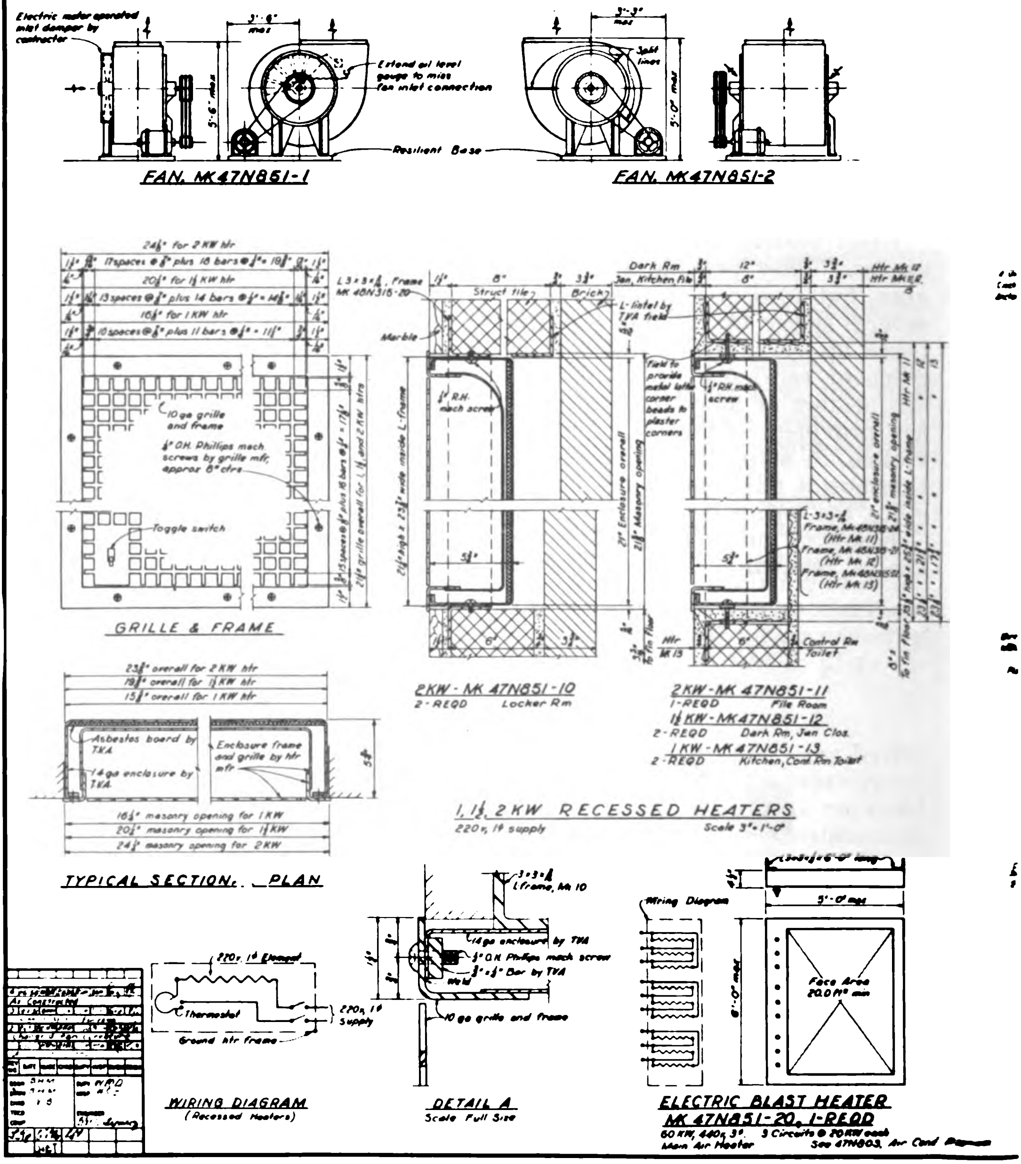
FIGURE 298.—*Roof ventilators for units 1 through 14 of Hales Bar powerhouse.*

47N851

CENTRIFU

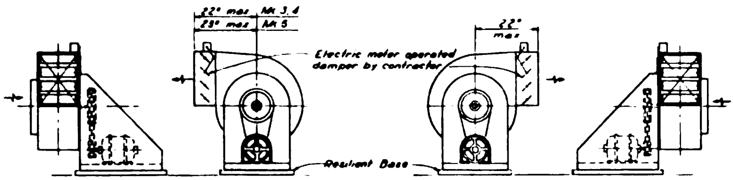
MARK NO. #	SERVICE & TITLE	FANS NO. REQD	LOCATION	INLET	WIDTH	BLADE CURVE	MIN CAP CFM	STATIC PRESSURE	OUTLET VEL MAX FPM	RPM MAX	SIDES MIN	SCROLL MIN	MATH ARRGT	TYPE
1	A C Supply Fan	1	47N803	Single	Single	Backward	10,000	1¼"	1625	725	12 Ga	14 Ga	3	2-Speed, Single [illegible]
2	Electrical Spaces Supply Fan	1	47N803	Double	Double	Backward	16,000	½"	1750	600	12	14	3	Squirrel Cage Induc[illegible]
3	Toilet Exhaust Fan	1	47N803	Single	Single	Forward	2,100	½"	1650	600	14	14	2	2 Speed Single [illegible]
4	Air Conditioning Rm Exh Fan	1	47N803	Single	Single	Forward	2,000	½"	1600	600	14	14	2	Squirrel Cage Induc[illegible]
5	Relay Rm Exhaust Fan	1	47N803	Single	Single	Forward	2,500	½"	1650	500	14	14	2	Squirrel Cage Induc[illegible]
6	Battery Rm Exhaust Fan	1	47N803	Single	Single	Forward	2,000	½"	1600	600	14	14	2	Squirrel Cage Induc[illegible]

Mark No. in above schedule prefixed by 47N851



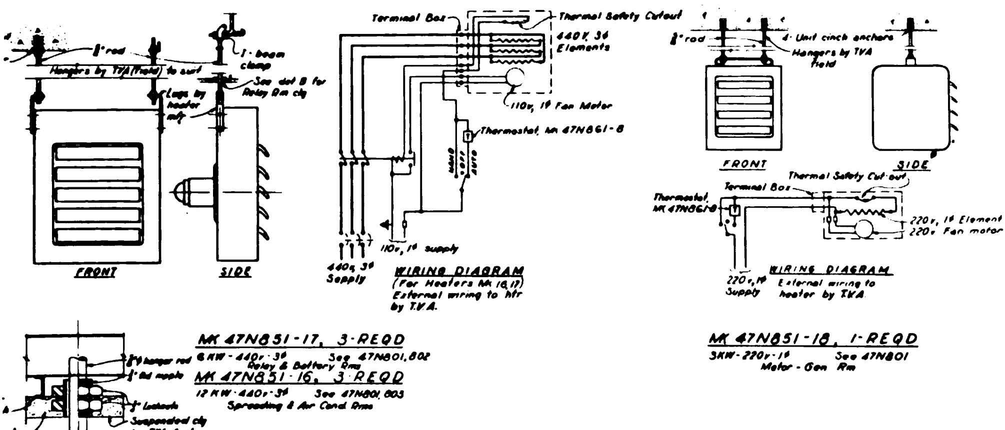
GAL FANS

	MOTORS					DRIVES	FITTINGS					REMARKS	MARK NO.
	VOLTS	PHASE	CYCLE	HP MIN	RPM MAX	TYPE	VOL DAMPER	DAMPER MOTOR	INLET GUARD	BELT GUARD	RESIL BASE		
	440	3	60	5/6	1200/600	V-belt	Inlet	Electric	None	Yes	Yes		1
	440	3	60	3	1200	V-belt	None	None	Yes	Yes	Yes	Ship knockdown	2
	440	3	60	1 1/2	1200/600	V-belt	Outlet	Electric	None	Yes	Yes		3
	440	3	60	1	1800	V-belt	Outlet	Electric	None	Yes	Yes		4
	440	3	60	1	1800	V-belt	Outlet	Electric	None	Yes	Yes		5
	440	3	60	1	1800	V-belt	Outlet	Electric	None	Yes	Yes	Protective Coating	6



FAN, MK 47N851-3
FAN, MK 47N851-4
FAN, MK 47N851-5

FAN, MK 47N851-6



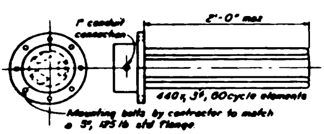
MK 47N851-17, 3-REQD
6 KW - 440v - 3φ See 47N801, 802
Relay & Battery Rm

MK 47N851-16, 3 REQD
12 KW - 440v - 3φ See 47N801, 803
Spreading & Air Cond Rms

MK 47N851-18, 1-REQD
3KW - 220v - 1φ See 47N801
Motor - Gen Rm

DETAIL B
Scale 6" = 1'-0"

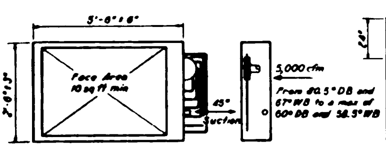
ELECTRIC UNIT HEATERS AND DIAGRAMS



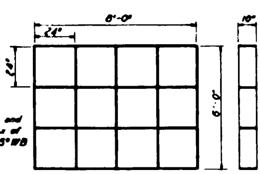
ELECTRIC IMMERSION HEATER, MK 47N851-19, 1-REQD
KW Humidifier Tank Heater See dwg 47N803

NOT TO SCALE

Not to scale
Except as noted



COOLING COIL, MK 47N851-25
2-Reqd See 47N803
Air Cond Plenum



FILTER ASSEMBLY, MK 47N851-30
1-Reqd See 47N803
Air Cond Plenum

CONTROL BUILDING
MECHANICAL HEATING, VENTILATING & AIR COND FANS, FILTERS, COILS AND HEATERS
HALES BAR PROJECT TENNESSEE VALLEY AUTHORITY DIVISION OF DESIGN
SUBMITTED: R M Gardner · RECOMMENDED: H G Petersen · APPROVED: R A Monroe
KNOXVILLE · 2-1-51 · 11 · M · 4 · 47N851R4

served from an air duct system. These are standard packaged units with fan, heating elements, and overload protection built in a casing designed for ceiling or wall mounting. All heaters, 3 kilowatts and above, are put on 480-volt, 3-phase, 60-cycle service, whereas smaller heaters are put on 240-volt, single-phase, 60-cycle service. Each heater is provided with a three-way switch reading "hand-off-auto."

In the office area, public toilets, and other spaces receiving special architectural treatment, recessed, gravity-convection heaters are provided. These are sized and designed for each installation to fit available openings and to conform to general architectural treatment. These are usually 3 kilowatts and less and are put on 240-volt, single-phase, 60-cycle service. The grille and front frame for these heaters were originally designed in one piece with the outer edge rigidly mounted to the embedded subframe, but experience has shown that the concentration of heat at the center portion of the grille caused buckling and warping. The grille and external frame are now designed as separate pieces with provision for the grille to expand and contract free from the frame.

Portable heaters are of the fan type in two sizes—3 kilowatts for 240 volts, single phase and 20 kilowatts for 480 volts, 3 phase. Receptacles are provided at points throughout the powerhouse and accompanying structures for their use.

Filters

All air supplied to air-conditioned systems and miscellaneous air supplied to areas where filtering is required passes through permanently installed filter banks made up of a number of individual removable cells. Each cell is of the replaceable-media type, using a paper felt to entrain the dust as it passes through. When the cells have become loaded to a point where the pressure drop, measured by permanently installed draft gages, reaches one-half inch of water, they are removed. The dirty, dust-laden felt is destroyed and a new felt is installed with the use of a specially designed loading machine purchased for each plant.

Cooling coils

All cooling coils are standard finned-type coils. The number of rows, arrangement of circuits, and size of each coil are carefully considered at the time of initial design in order to obtain a coil to handle the cooling load and to fit space available.

Humidifiers

All humidifiers are of the open-pan type consisting of a semicylindrical open tank located inside the plenum, with an immersed electric heater. The controlling device is a humidistat located in the space being served or in the return duct from it. The humidistat controls the holding coil of the magnetic contactor for the immersion heater. Upon a drop in humidity the heater is energized, boiling the water which emits live steam into the air stream. Water level in the open tank is maintained by a mechanical float-type water feeder with a low water cutoff to stop the immersion heater on an excessive drop in water level.

Controls

All heating is controlled directly by thermostats located in the space or in a return duct from it. All heaters rated at 3 kilowatts or less are served by a 240-volt, single-phase service and are controlled by a thermostat in series with the heater. All heaters rated in excess of 3 kilowatts are served by 480-volt, 3-phase service and are controlled by thermostats in series with the holding coil of the contactor. All duct blast-type heaters above 20 kilowatts are designed with two or more circuits. Heaters of 2 or 3 circuits are controlled by a thermostat for each circuit with the temperature settings of the thermostats staggered. On heaters of four or more circuits a programer is used, controlled from a single modulating thermostat which operates the separate circuits in steps. A limit thermostat is provided for each blast heater, located adjacent to the elements on the leaving air side. Upon excessive temperature this thermostat stops all circuits of the blast heater to prevent overheating. The offices, public spaces, toilets, etc., are heated to 72° F. Shops, erection areas, and similar spaces are heated to 60° to 65° F. Spaces where only prevention of freezing is desired are heated to 40° F.

Humidity is controlled by a humidistat located in the space or in the return duct from it. The humidistat is placed in series with the holding coil of the immersion heater in the humidifier to operate the heater upon a drop in humidity. The humidity is maintained between 40 and 50 percent relative.

In chilled water systems cooling is controlled by regulating the flow of chilled water through finned-type coils by three-way, double-seated, motor-operated valves activated by modulating thermostats located in the return duct from the spaces served. The controlling thermostats are compensated by other thermostats located in the fresh air. The thermostats are so adjusted as to produce a temperature of 78° F. dry bulb in the conditioned spaces until the outside air rises to 85° F. dry bulb. As the outside temperature continues to rise, the outside air thermostat overrides the controlling thermostat so that when the outside air reaches 100° F. dry bulb, the inside temperature will be 84° F. dry bulb.

In direct expansion cooling systems, temperature is controlled by controlling the flow of refrigerant through the thermal expansion valve on each cooling coil. A solenoid valve is located in each liquid line to the coil. The solenoid valves are controlled by thermostats placed in the return air duct from the spaces served. These thermostats have their settings staggered to cut the coils in and out of operation in steps. These thermostats are set usually to maintain a constant temperature of 78° to 80° F. dry bulb.

All air-conditioning systems serving a number of rooms or spaces have a branch duct air supply system. Systems of this type have zone duct controls, consisting of motor-operated dampers, thermostats, and switchover control switches. The switchover control switches are multiple-pole, double-throw type located on the control panel of the switchboard which allows the correct operation of the branch duct damper motors for either heating or cooling. The air supplied to a given space is controlled by a room type modulating thermostat which is compensated by a thermostat located in the fresh air. The room thermostats are so adjusted as to produce a

room condition of 78° F. dry bulb while the outside temperature rises to 85° F. dry bulb. As the outside temperature continues to rise the compensating thermostat overrides the room thermostat so that when the outside temperature reaches 100° F. dry bulb the inside temperature is 84° F. dry bulb.

All duct systems having zone duct controls are provided with a static pressure control to maintain a constant pressure in the ducts which prevents an excess of air being supplied to any outlet. The supply fan has a motor-operated inlet damper controlled by a static pressure regulator which measures the static pressure in the duct leading from the fan discharge and controls the position of the inlet damper. This maintains a constant pressure in the duct.

A draft gage across each filter bank indicates when the filters are sufficiently clogged with dirt to require reloading. Design of fan static pressure is based on a pressure drop across the filters not to exceed one-half inch of water.

All controls in any given air-conditioning system are so designed and switched as to have only controls relative to cooling energized when the master selector switch is in "Cool" position, and likewise to have only controls relative to heating energized when the master switch is in "Heat" position.

Wire guards, dampers, and louvers

All wire guards, dampers, and louvers are designed and detailed to fit the exact requirements, especially of size, for each application.

Wire guards are used to cover duct openings, dampers, or wall openings and to provide protection for the equipment behind them. These are constructed with a 2- by ⅝- by 10-inch USSG rolled channel rectangular frame, with corners mitered, welded, and ground smooth. The mesh of the wire guards consists of ¼-inch-round rods spaced 1 inch on centers inserted in drilled holes of the frame and plug welded. Intermediate drilled mullions are provided as required to support the rods and to prevent loose rattling. The wire guards are mounted by the use of oval head machine screws through the face of the frame into embedded square tube frames. All wire guards are hot-dipped galvanized after fabrication with not less than 2 ounces of zinc per square foot.

Dampers are designed and detailed to fit the exact requirements for each application and they are purchased from TVA detailed drawings. Dampers, such as shown in figure 299, are fabricated with 2-inch-wide structural channel frame and leaves of No. 14 USSG sheet steel blades linked together to operate as a unit. All linkage is of bronze pin and bronze washer construction to prevent the seizing of mating surfaces due to corrosion. All bearings are oil-impregnated bronze-mounted in the damper frame. On all manually operated dampers a spring-type friction device is used at one or more of the connecting points between the linkage and blades to hold the blades at any desired opening setting. All fire dampers are counterweighted to go shut. They are held in "Open" position by a chain to CO_2 release on the fire-protection system, which releases the chain at any time the fire-protection system is energized. All dampers including blades, frames, shafts, and linkages are hot-dipped galvanized after fabrication with not less than 2 ounces of zinc per square foot of actual surface.

Louvers are placed in all exterior air openings to permit the passage of air and to prevent the entrance of moisture. All louvers are equipped with a 3-by-3 mesh hardware cloth screen to prevent the entrance of large insects and birds. The louvers are designed, detailed, and purchased for each application and are fabricated from No. 14 USSG galvanized sheets with all joints of continuous weld or braze. All surfaces, void of galvanizing, are cleaned and given a coat of red lead and a final coat of aluminum paint.

A typical wire guard, damper, and louver procurement drawing is shown in plate 42.

Grilles and ceiling outlet fixtures

All grilles and ceiling outlet fixtures are of standard manufacture or, in locations where architectural treatment is such that standard manufactured products do not fit in with the overall style, the grilles or ceiling outlet fixtures are designed by TVA engineers. Grilles are used for sidewall installation, and ceiling outlet fixtures are used for all overhead installations. In selecting the grille or fixture a number of considerations are made. The size, style, and spacing must be such as to provide the correct air characteristics of volume, distribution, and air throw and at the same time fit the overall architectural and lighting schemes. All fixtures purchased are of aluminum or with electroplated finishes of cadmium, satin chrome, or dull satin nickel to match metal door and window frames and to give a surface that can easily be cleaned. Figure 300 (p. 614) shows a typical return air grille and figures 282 and 301 (pp. 582 and 615) illustrate two types of ceiling outlet fixtures.

Ductwork

All ductwork for air-conditioning systems and general ventilating systems is fabricated from standard galvanized sheets. The ducts are fabricated in accordance with accepted practice. Longitudinal joints are the Pittsburgh lock, and cross joints are standing seam construction as shown at the lower left in plate 43. Small ducts

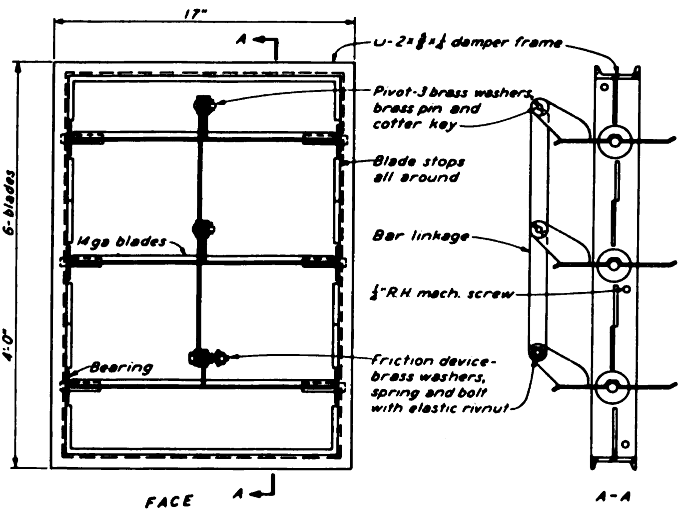
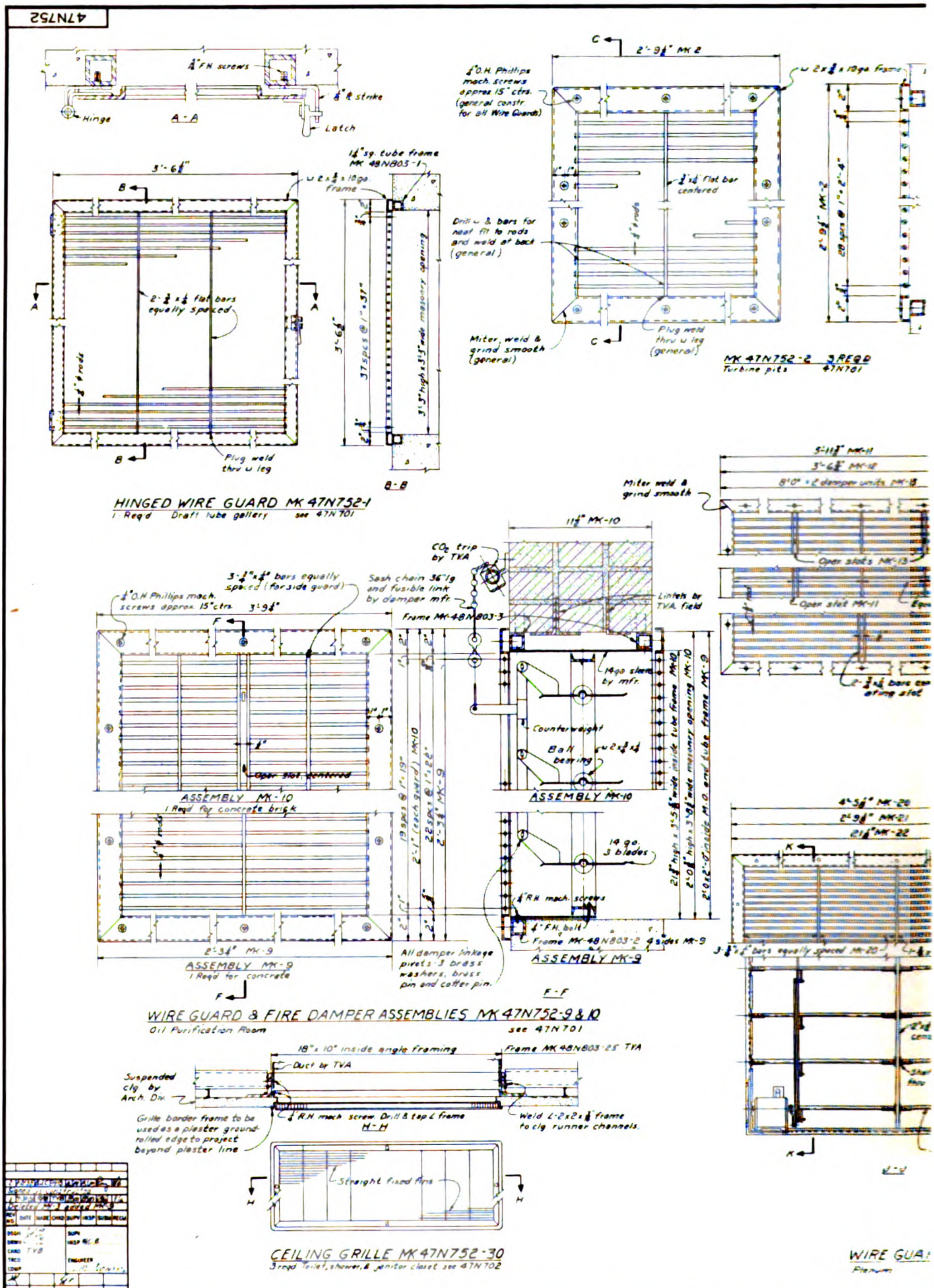


Figure 299.—*Typical damper details.*


47N752
HINGED WIRE GUARD MK 47N752-1
1 Req'd Draft tube gallery see 47N701
MK 47N752-2 3 REQD
Turbine pits 47N701
WIRE GUARD & FIRE DAMPER ASSEMBLIES MK 47N752-9 & 10
Oil Purification Room see 47N701
ASSEMBLY MK-10
1 Req'd for concrete brick
ASSEMBLY MK-9
1 Req'd for concrete
CEILING GRILLE MK 47N752-30
3 req'd Toilet, shower, & janitor closet see 47N702
Hinge
Latch
Plug weld thru ⊔ leg
Miter, weld & grind smooth (general)
Counterweight
Ball bearing
Straight fixed fins

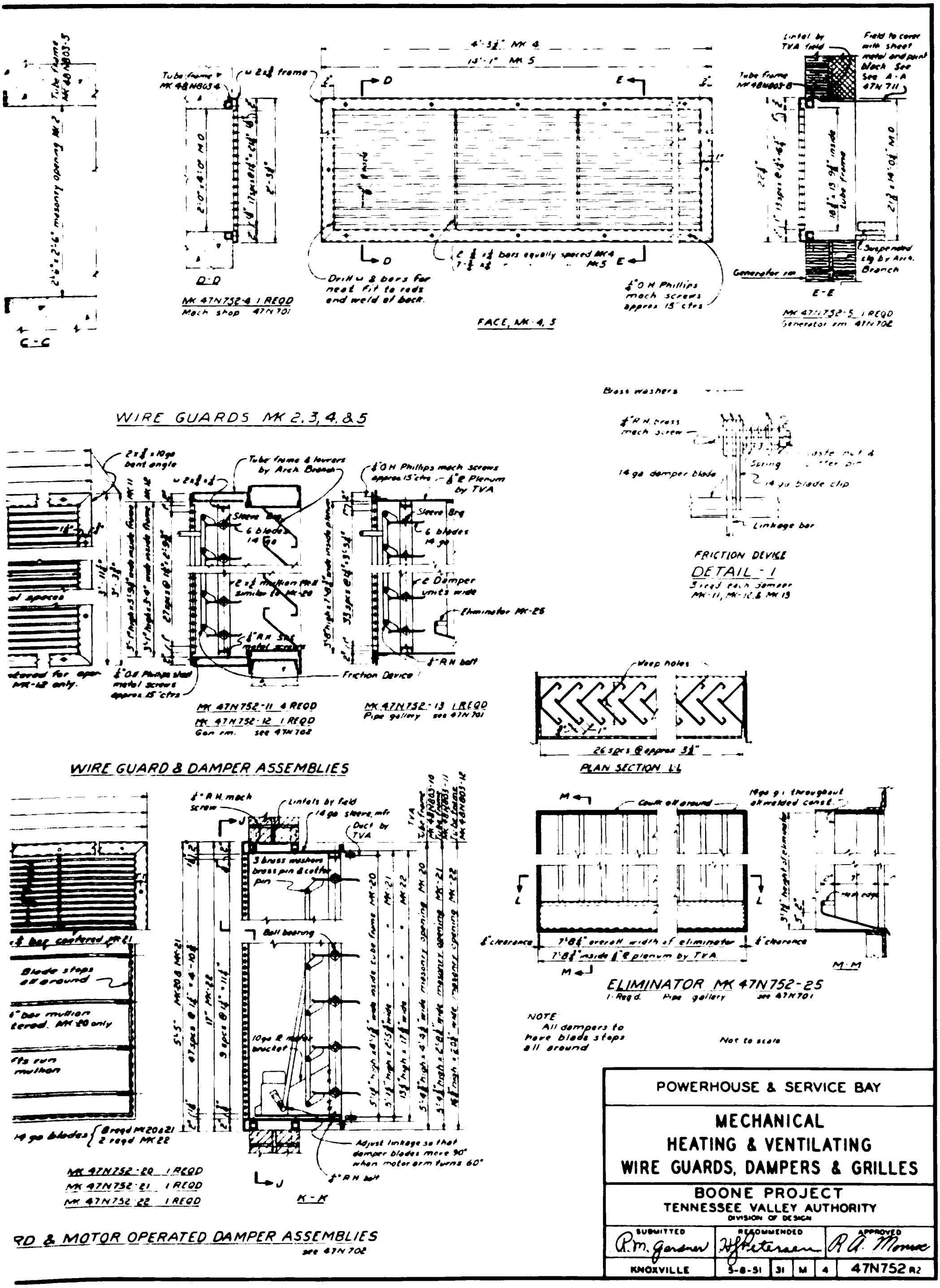
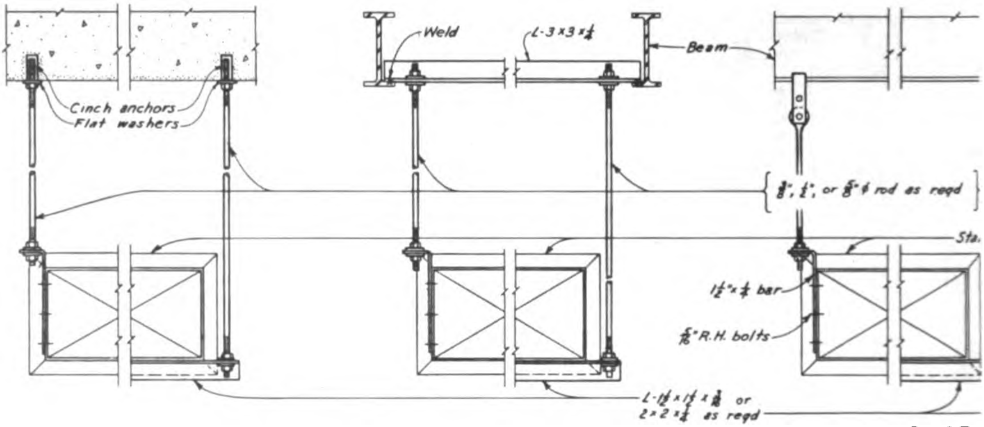
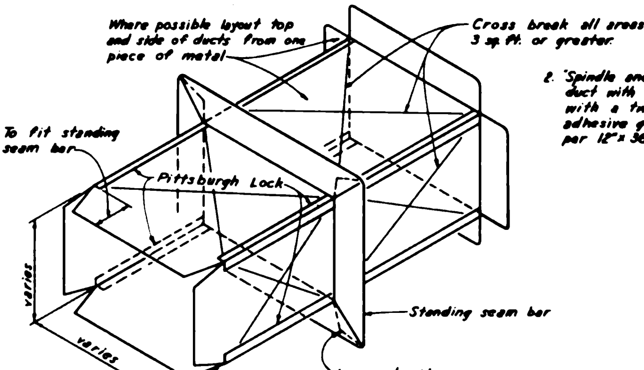

WIRE GUARDS MK 2, 3, 4, & 5
FACE, MK 4, 5
D-D
C-C
E-E
MK 47N752-4 1 REQD
MK 47N752-5 1 REQD
FRICTION DEVICE
DETAIL - I
WIRE GUARD & DAMPER ASSEMBLIES
MK 47N752-11 4 REQD
MK 47N752-12 1 REQD
MK 47N752-13 1 REQD
PLAN SECTION L-L
ELIMINATOR MK 47N752-25
M-M
K-K
MK 47N752-20 1 REQD
MK 47N752-21 1 REQD
MK 47N752-22 1 REQD
RD & MOTOR OPERATED DAMPER ASSEMBLIES
NOTE
All dampers to have blade stops all around
Not to scale
POWERHOUSE & SERVICE BAY
MECHANICAL
HEATING & VENTILATING
WIRE GUARDS, DAMPERS & GRILLES
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
5-8-51
47N752 R2

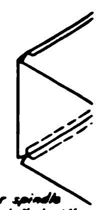
PLATE 42

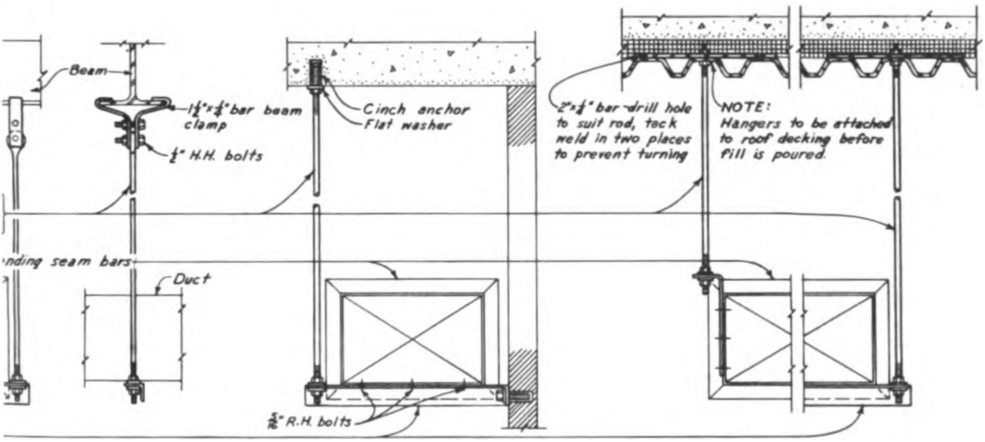


DUCT
Approximate location of duct
to determine exact location. U
particular location



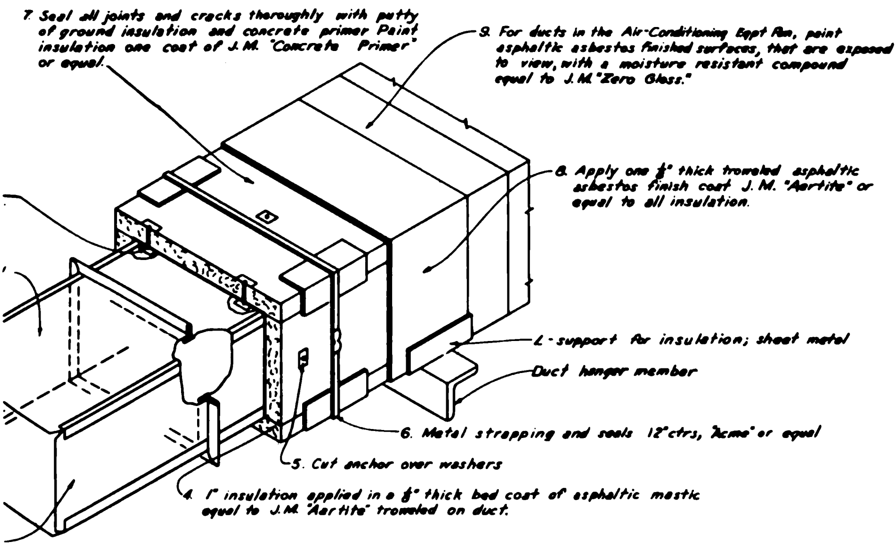
NONINSULATED DUCT





HANGERS

hangers shown on plan drawings. Field
lse type best adapted to each



INSULATED DUCT

AIR CONDITIONING
DUCT HANGERS AND
DUCT FABRICATION DETAILS

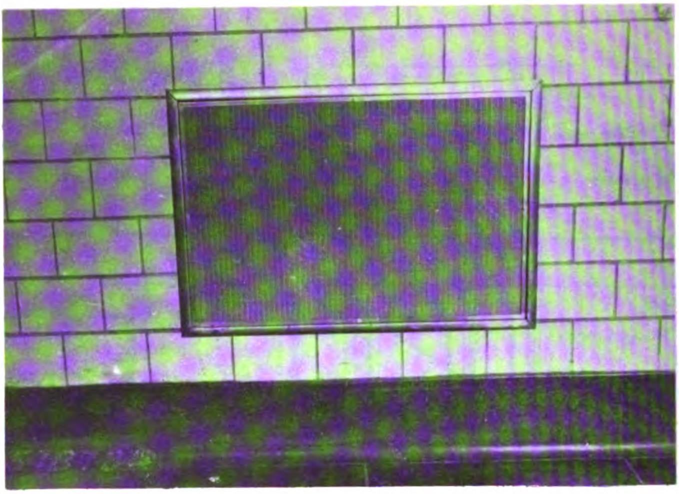


FIGURE 300.—*Typical return air grille.*

are supported by strap hangers attached directly to the side of the duct. Large ducts are supported on structural angles hung from above by round rods. Typical duct hangers are shown at the top in plate 43. No metal lighter than No. 22 USSG is used in duct construction. All ducts with a maximum side of 0 to 36 inches usually are fabricated from No. 22 USSG sheets with all panels cross broken for additional rigidity and strength. All ducts with a maximum side of 36 to 48 inches usually are fabricated from No. 20 USSG sheets with the panels cross broken or reinforced with 1- or 1½-inch angles. All ducts with a maximum side in excess of 48 inches are usually fabricated by riveting No. 18 USSG sheets to a welded angle frame. Ducts handling air from spaces where corrosive fumes are present, such as battery charging rooms, are fabricated from metal best suited to resist the fumes. Plate 44 shows the details of a heating and ventilating duct system for Fontana project and plate 45 illustrates an air-conditioning duct arrangement at Boone project.

Air-conditioning plenums

The air-conditioning plenums are constructed to house the filters, cooling coils, electric blast heater, humidifier, and control and indicating devices. The main frame of the plenum is constructed of 3- by 3- by ¼-inch angles with intermediate members so spaced and sized as to support the coils, heater, filters, dampers, and doors. The frame is covered with No. 18 USSG galvanized sheet metal and riveted. The entire plenum is insulated.

The details of the air-conditioning plenums at Boone project are shown in plate 46, and a view of the completed plenum at the Chickamauga project is shown in figure 302.

FIGURE 301.—*Ceiling outlet fixtures of manufacturer's standard design—Hiwassee.*

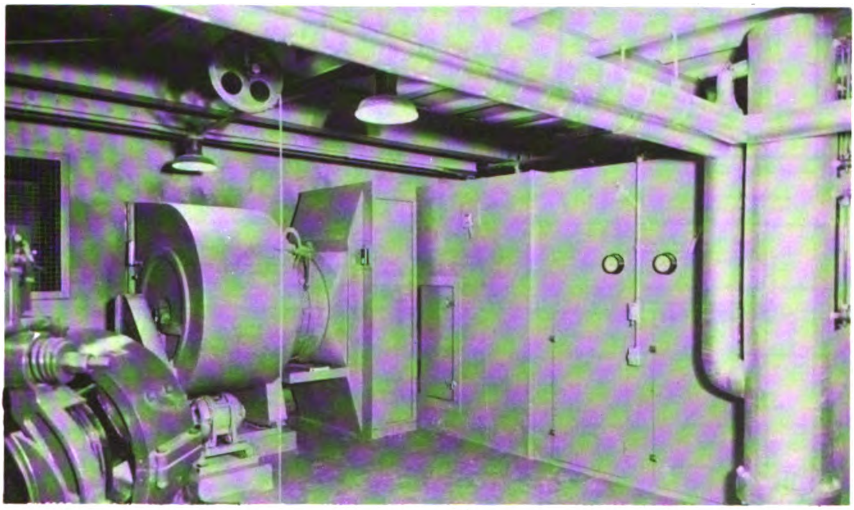
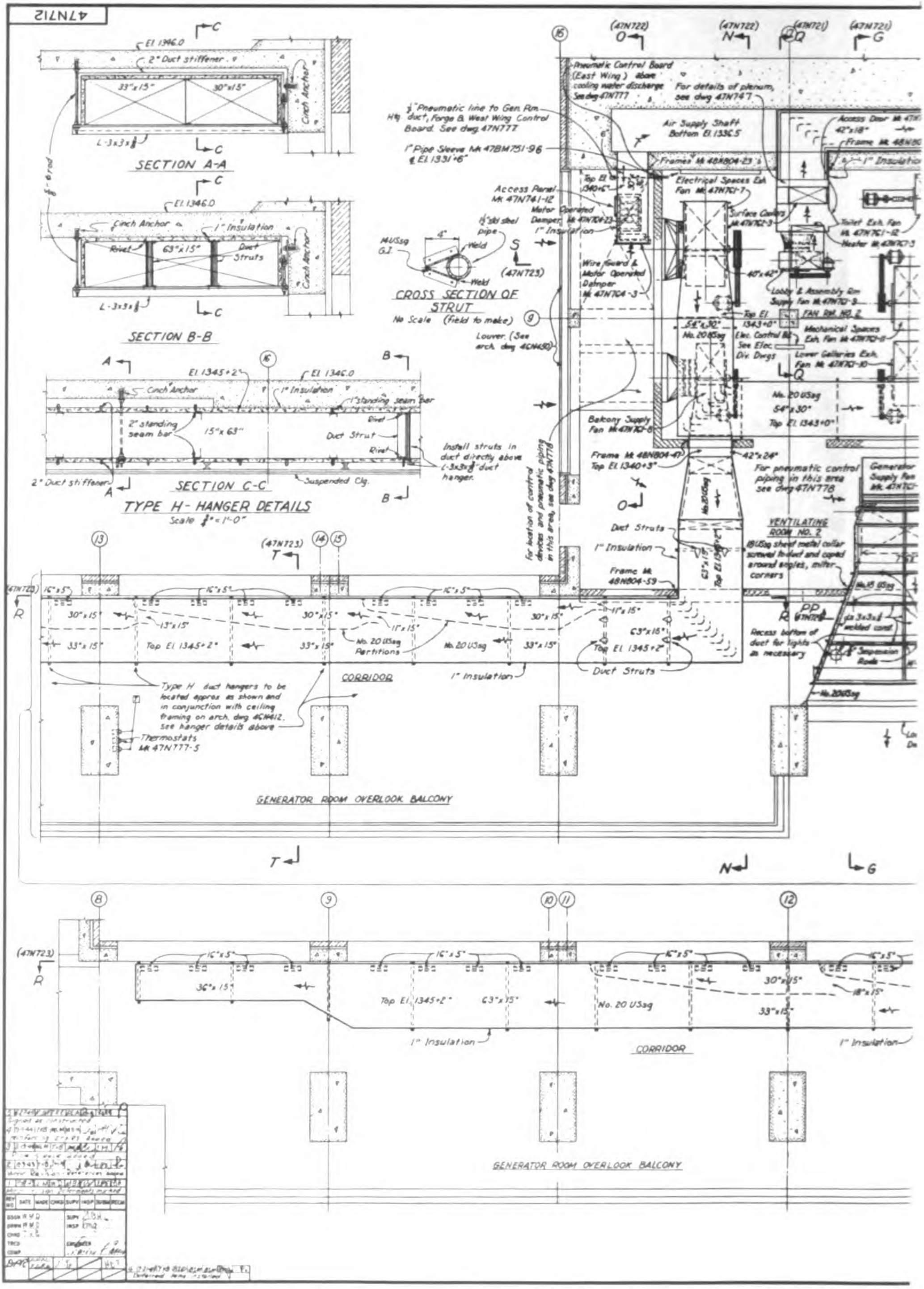


FIGURE 302.—*Air-conditioning plenum—Chickamauga.*

498128 O—60——41


47N712
SECTION A-A
SECTION B-B
SECTION C-C
TYPE H- HANGER DETAILS
CROSS SECTION OF STRUT
CORRIDOR
GENERATOR ROOM OVERLOOK BALCONY
VENTILATING ROOM NO. 2

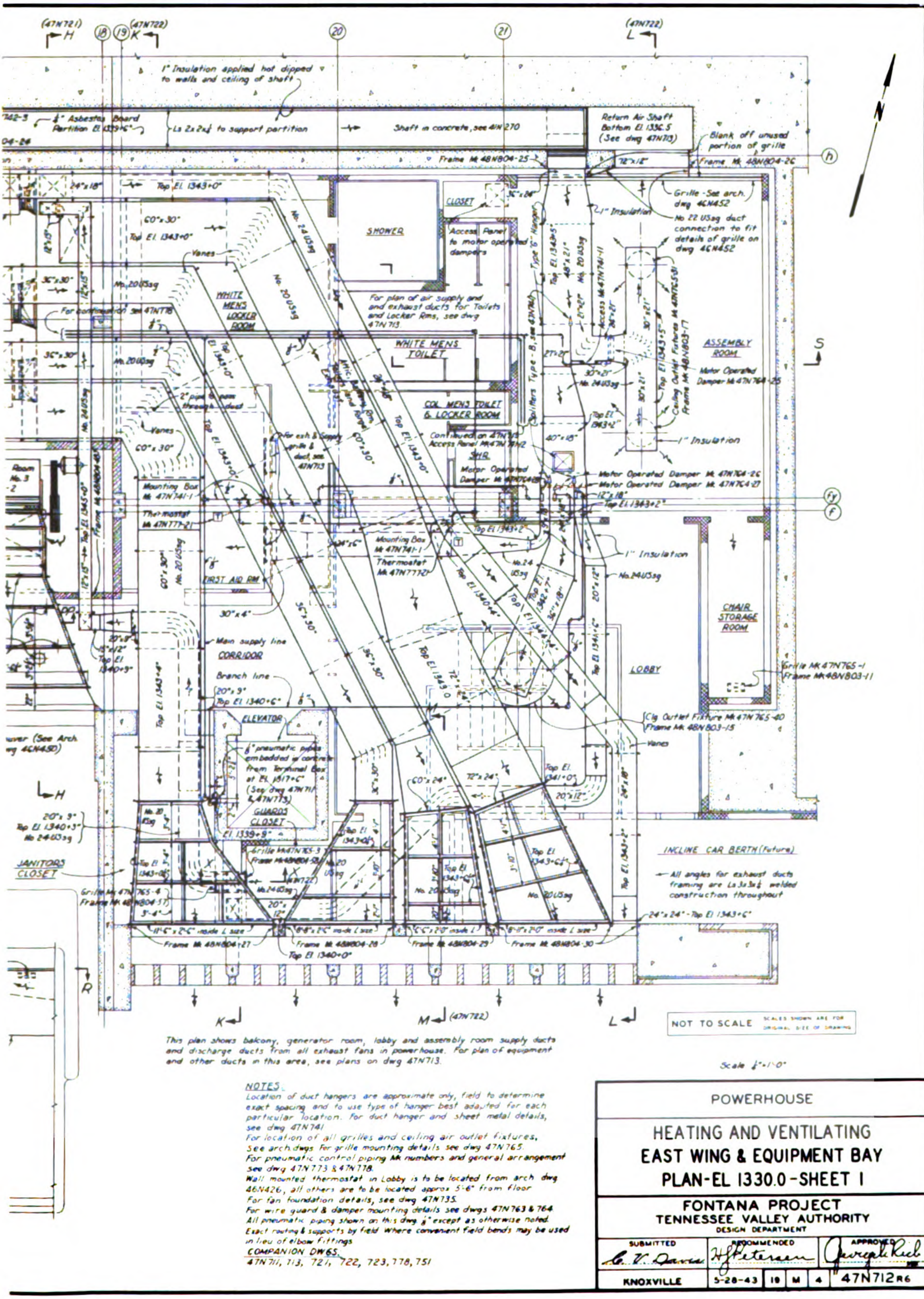
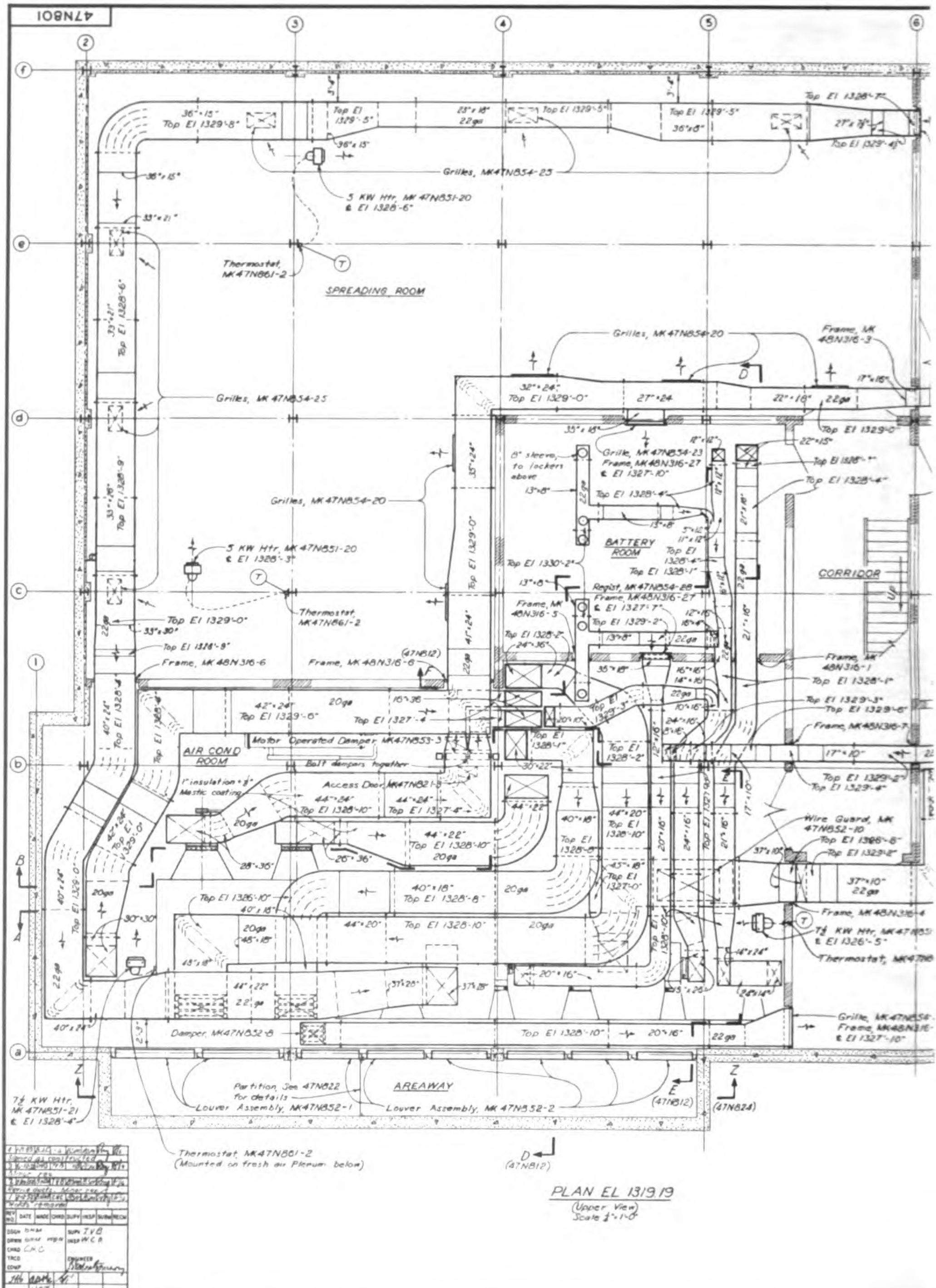
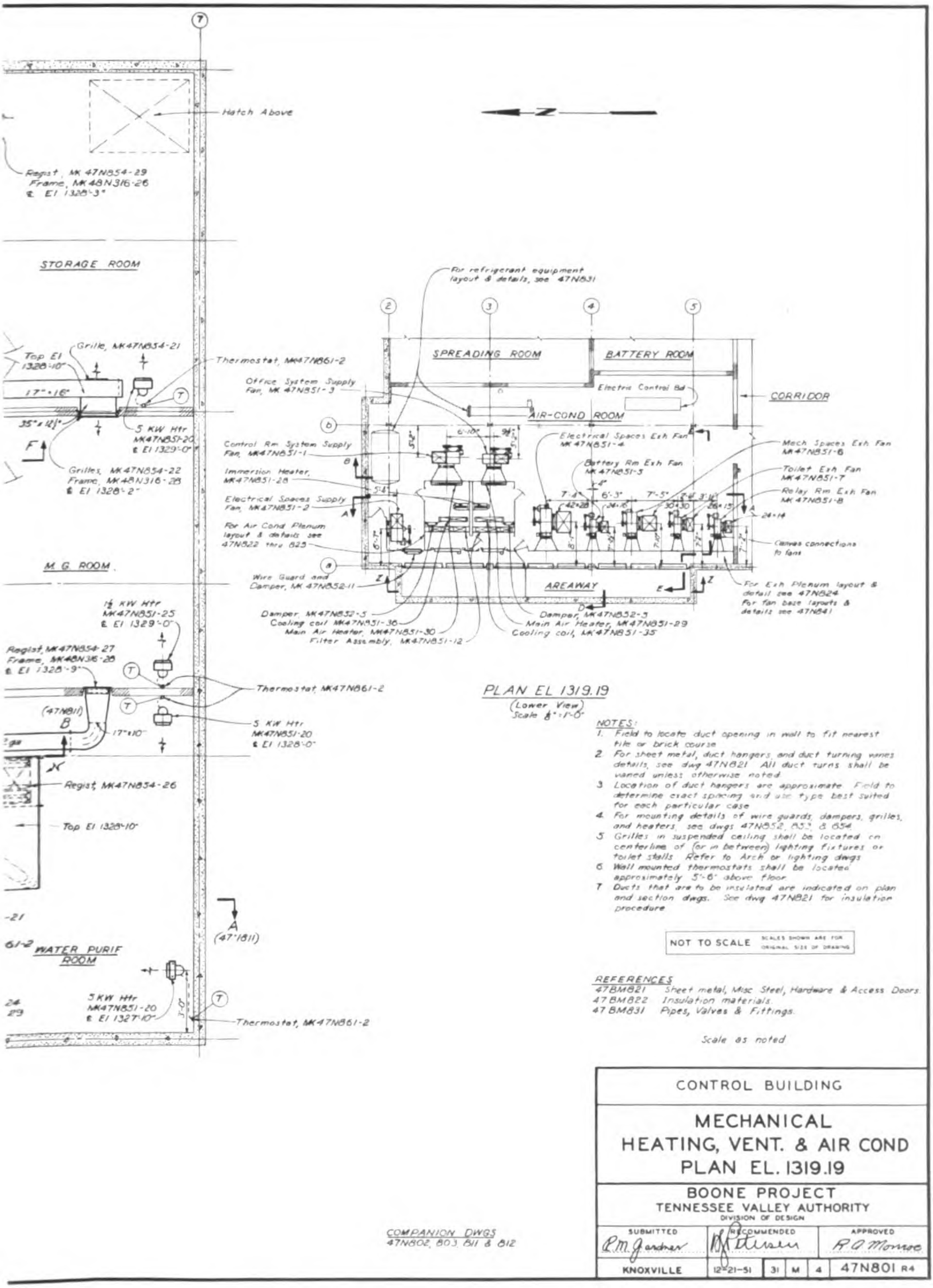
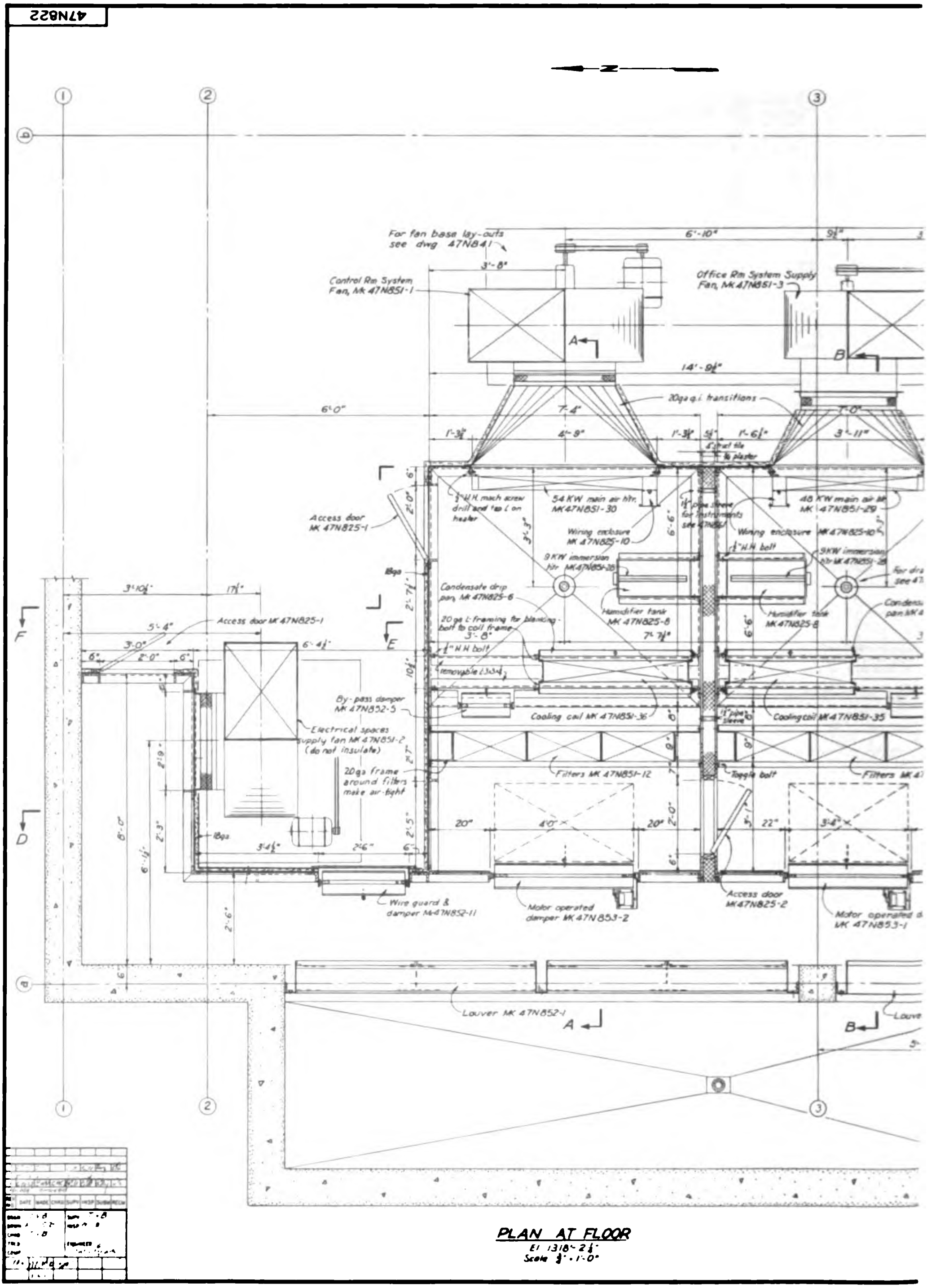

This plan shows balcony, generator room, lobby and assembly room supply ducts and discharge ducts from all exhaust fans in powerhouse. For plan of equipment and other ducts in this area, see plans on dwg 47N713.
NOT TO SCALE
Scale ¼"=1'-0"
NOTES:
Location of duct hangers are approximate only, field to determine exact spacing and to use type of hanger best adapted for each particular location. For duct hanger and sheet metal details, see dwg 47N741
For location of all grilles and ceiling air outlet fixtures, See arch dwgs For grille mounting details see dwg 47N765.
For pneumatic control piping Mk numbers and general arrangement see dwg 47N773 & 47N778.
Wall mounted thermostat in Lobby is to be located from arch dwg 46N426, all others are to be located approx 5'-6" from floor
For fan foundation details, see dwg 47N735.
For wire guard & damper mounting details see dwgs 47N763 & 764.
All pneumatic piping shown on this dwg ⅜" except as otherwise noted. Exact routing & supports by field Where convenient field bends may be used in lieu of elbow fittings
COMPANION DWGS.
47N711, 713, 721, 722, 723, 778, 751
POWERHOUSE
HEATING AND VENTILATING
EAST WING & EQUIPMENT BAY
PLAN-EL 1330.0-SHEET 1
FONTANA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
5-28-43
47N712 R6

PLATE 44



47N801
SPREADING ROOM
AIR COND ROOM
BATTERY ROOM
CORRIDOR
AREAWAY
Grilles, MK47N854-25
Grilles, MK47N854-20
5 KW Htr, MK 47N851-20
Thermostat, MK47N861-2
Motor Operated Damper, MK47N853-3
Bolt dampers together
Access Door, MK47N821-3
1" insulation + 1/8" Mastic coating
Damper, MK47N852-8
Louver Assembly, MK47N852-1
Louver Assembly, MK 47N852-2
Partition, See 47N822 for details
Frame, MK 48N316-6
Wire Guard, MK 47N852-10
7 1/2 KW Htr, MK 47N851-21
Thermostat, MK47N861-2 (Mounted on fresh air Plenum below)
8" sleeve, to lockers above
PLAN EL 1319.19
(Upper View)


Hatch Above
STORAGE ROOM
M G ROOM
WATER PURIF ROOM
SPREADING ROOM
BATTERY ROOM
AIR-COND ROOM
CORRIDOR
AREAWAY
For refrigerant equipment layout & details, see 47N831
Thermostat, MK47N861-2
5 KW Htr MK47N851-20
PLAN EL 1319.19
(Lower View)
Scale 1/8"=1'-0"
NOTES:
1. Field to locate duct opening in wall to fit nearest tile or brick course
2. For sheet metal, duct hangers and duct turning vanes details, see dwg 47N821. All duct turns shall be vaned unless otherwise noted
3. Location of duct hangers are approximate. Field to determine exact spacing and use type best suited for each particular case
4. For mounting details of wire guards, dampers, grilles, and heaters, see dwgs 47N852, 853, & 854
5. Grilles in suspended ceiling shall be located on centerline of (or in between) lighting fixtures or toilet stalls. Refer to Arch or lighting dwgs
6. Wall mounted thermostats shall be located approximately 5'-6" above floor
7. Ducts that are to be insulated are indicated on plan and section dwgs. See dwg 47N821 for insulation procedure
NOT TO SCALE
REFERENCES
47BM821 Sheet metal, Misc Steel, Hardware & Access Doors
47BM822 Insulation materials
47BM831 Pipes, Valves & Fittings
Scale as noted
COMPANION DWGS
47N802, 803, 811 & 812
CONTROL BUILDING
MECHANICAL
HEATING, VENT. & AIR COND
PLAN EL. 1319.19
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
12-21-51
47N801 R4



PLAN AT FLOOR
El 1318'-2½"
Scale ⅜" = 1'-0"

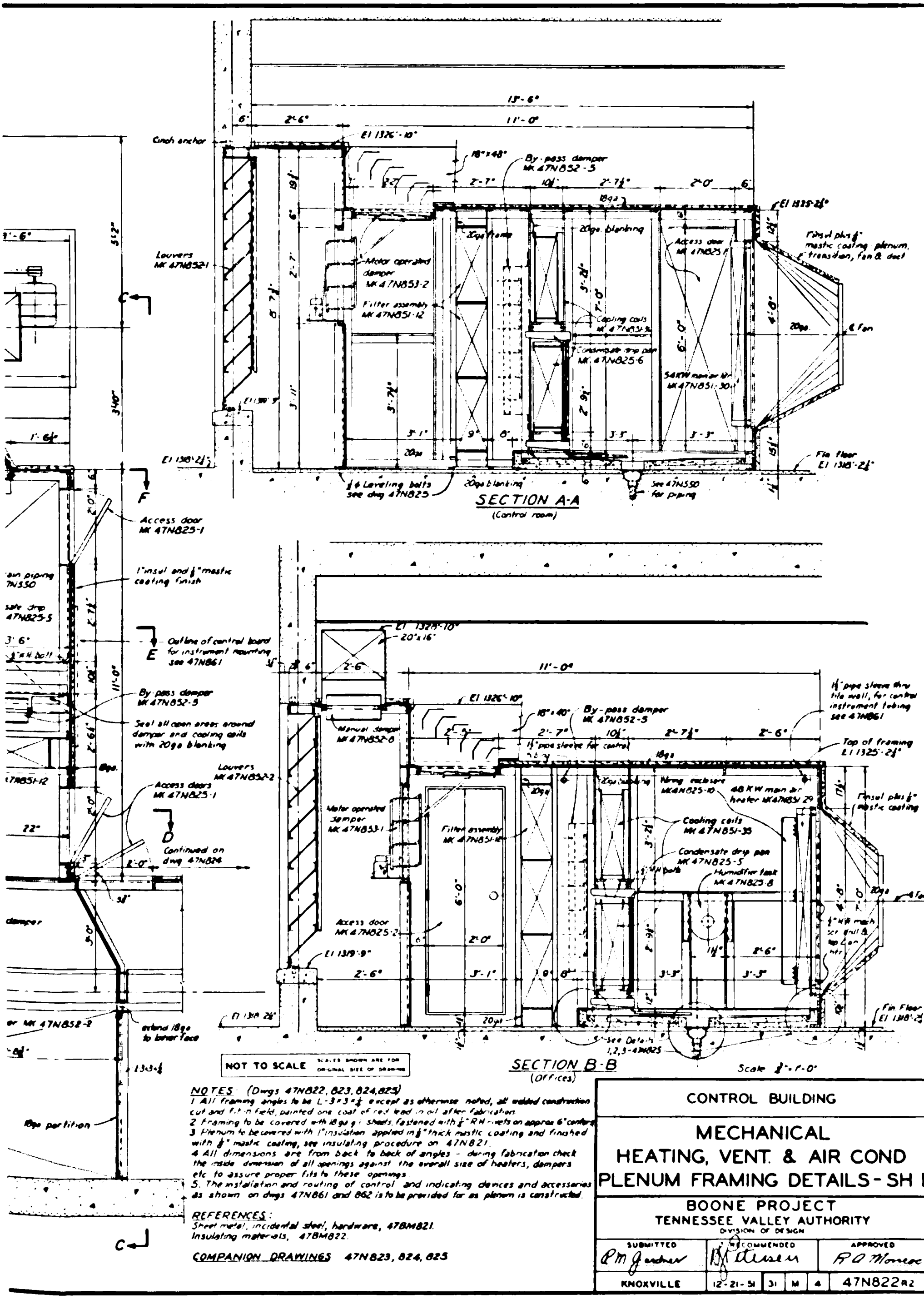

SECTION A-A
(Control room)
SECTION B-B
(Offices)
NOT TO SCALE
Scale 3/4" = 1'-0"
NOTES (Dwgs 47N822, 823, 824, 825)
1 All framing angles to be L-3×3×1/4 except as otherwise noted, all welded construction cut and fit in field, painted one coat of red lead in oil after fabrication.
2 Framing to be covered with 18 ga g.i. sheets, fastened with 1/4" RH rivets on approx 6" centers
3 Plenum to be covered with 1" insulation applied in 1/8" thick mastic coating and finished with 1/8" mastic coating, see insulating procedure on 47N821.
4 All dimensions are from back to back of angles - during fabrication check the inside dimension of all openings against the overall size of heaters, dampers etc to assure proper fits to these openings
5. The installation and routing of control and indicating devices and accessories as shown on dwgs 47N861 and 862 is to be provided for as plenum is constructed.
REFERENCES:
Sheet metal, incidental steel, hardware, 47BM821.
Insulating materials, 47BM822.
COMPANION DRAWINGS 47N823, 824, 825
CONTROL BUILDING
MECHANICAL
HEATING, VENT. & AIR COND
PLENUM FRAMING DETAILS - SH 1
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
12-21-51
47N822 R2

PLATE 46

Insulation

All air-conditioning supply ducts and plenums are insulated to prevent heat gain and to prevent the forming of condensation on the bare metal ducts. At hydro plants where generator hatch covers are provided and at plants where outdoor-type generators are used, the hatch covers and generator housings are insulated on the inside to reduce the heat buildup due to solar radiation. All chilled water piping in air-conditioning system is insulated to prevent condensation and for the conservation of cooling effect.

The exact method and materials of insulation have changed through the years as additional experience has been gained and as new material and methods are developed. TVA's present method of insulating air-conditioning ducts and plenums, as shown at the lower right in plate 43, page 612, is as follows:

1. Clean the bare duct and brush free of all dirt, dust, plaster, and foreign material.
2. Insulation spindle anchors are fastened to the bare duct with an approved adhesive. The anchors are applied with a twisting motion to ensure wet adhesive gripping both surfaces. Six anchors are used for each 12- by 36-inch insulating board.
3. The duct is painted with an asphalt base primer after the anchors are applied.
4. Insulation, in the form of rigid vegetable cork boards, 36 by 12 by 1 inch, is next applied over the spindle anchors in a ⅛-inch-thick bed coat of asphaltic mastic.
5. Holding washers are applied to the spindles and pushed down tight. The excess spindle is cut off next to the washer.
6. All duct insulation is then strapped on 12-inch centers with standard ½-inch strapping material and seals. All corners of insulation under the straps are protected by the use of bent sheet metal protectors.
7. All joints, cracks, and voids are filled and sealed with a putty of ground insulation and asphaltic primer. All surfaces then are given a coat of asphaltic primer.
8. The surface of all insulation then is given a ⅛-inch finish coat of asphaltic mastic.
9. All surfaces exposed to view are painted with moisture resisting, asphalt base compound.

The generator housings and hatch covers are insulated in the following manner:

1. All metal surfaces to be insulated are cleaned and brushed free of dirt.
2. Insulation spindle anchors are fastened to the bare metal with an approved adhesive. The anchors are applied with a twisting motion to ensure wet adhesive gripping both surfaces. Six anchors are used for each 12- by 36-inch insulating board.
3. All surfaces to be insulated are painted with an asphaltic primer.
4. Insulation, in the form of rigid vegetable cork boards, 36 by 12 by 1 inch is next applied, hot-dipped in asphalt and pressed firmly in place over the spindle anchors.
5. Anchor washers are next applied over the spindles and pushed down tight. Expanded metal lath is applied over the insulation and the extended spindles are bent over tight against the metal lath, holding it in place.
6. Two final trowel coats of approximately ⅛-inch-thick asphaltic mastic are then applied.
7. The surface is then painted to match the overall color scheme.

The chilled water piping, fittings, and specialties are insulated with standard premolded pipe covering and fitting insulation of

vegetable cork and applied in the manner as recommended by the manufacturer.

Piping

All water piping for chilled water and condensing water is standard black steel pipe with black malleable iron fittings. All piping, fittings, valves, and specialties 2½-inch iron pipe size and smaller are of standard screwed construction. All piping, fittings, valves, and specialties 3-inch iron pipe size and larger are of welded or flanged construction. Cooling water valves are gate, glove, and swing check type of bronze construction in smaller sizes and of IBBM construction for larger sizes.

All refrigerant piping installed by TVA consists of hard-drawn type K copper tubing and standard wrought copper solder fittings, using hard solder.

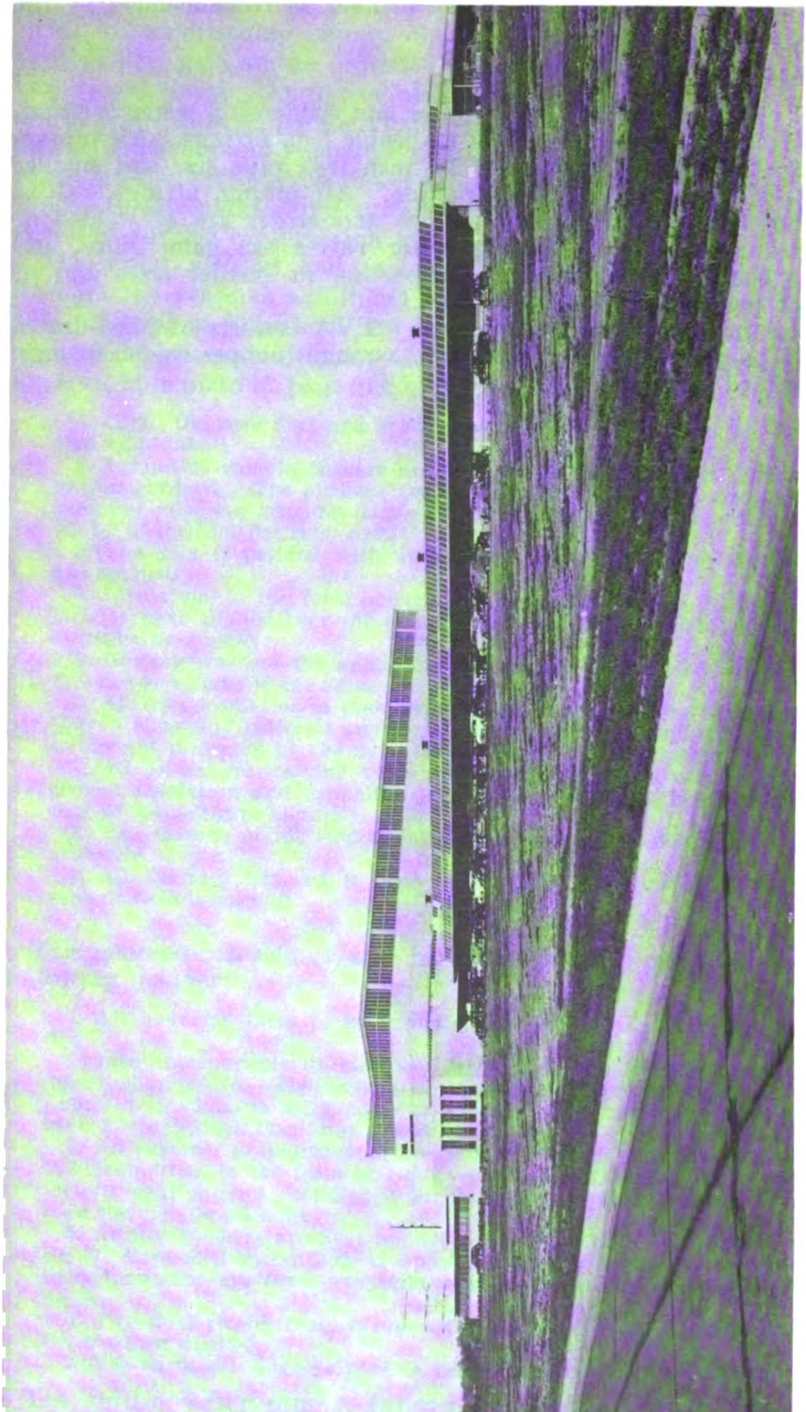


FIGURE 303.—*Power Service Building at Wilson Reservation contains central repair shops for power system.*

CHAPTER 15

MACHINE SHOPS

Each TVA hydro plant has a permanent machine shop and tool room with sufficient equipment and small tools to take care of all normal maintenance repair work required at the plant. The size of the shops and the amount of equipment in them vary according to the capacity of the generating facilities and to some extent with the proximity of the plant to other fully equipped TVA maintenance or hydro plant shops and outside repair facilities. It is not intended that an individual project machine shop be completely equipped to make all major repairs which may be required or necessary.

Table 14 lists the equipment provided and the space allotted for each of the individual hydro plant machine shops, including the tool rooms, in TVA-built plants. It will be noted that all main river plants, except Watts Bar and the tributary plants at Norris, Hiwassee, Cherokee, Douglas, Fontana, and Watauga, are each provided with the normal complement of machines, consisting of an engine lathe, bench lathe, shaper, upright drill, sensitive drill, metal cutting saw, two-wheel grinder, tool post grinder, portable pipe threader, forge, anvil, and arbor press. Operating experience has shown that these machine tools are sufficient to take care of normally expected repair work in the larger generating stations.

Watts Bar hydro plant does not have the larger machine tools since a fully equipped machine shop is installed at Watts Bar Steam Plant some 3,500 feet downstream from the hydro plant. Similarly, the completely equipped Hiwassee machine shop serves as a central repair shop for the smaller Ocoee No. 3, Apalachia, Chatuge, and Nottely projects. In the Upper Holston area the Watauga project machine shop also serves the Wilbur, South Holston, Boone, and Fort Patrick Henry projects.

In May 1947 the TVA Board of Directors approved construction of the power service building at Wilson Reservation. The purpose of this project was to provide a main warehouse and shop facilities for the operation, maintenance, and transmission line construction of the entire TVA power system, together with certain facilities for the local area. These facilities were needed and had been scheduled for construction at the beginning of World War II, but their construction was deferred due to wartime restrictions. Prior to construction of the power service building the utility building at Wilson hydro plant had handled the repair work for the hydro plant and the surrounding area. This new central repair and warehouse facility replaced obsolete, unsafe, and uneconomical facilities. The facilities were inadequate for meeting the prewar power system and fell far short of meeting the requirements of the 1947 power system which at that time had doubled in capacity since the beginning of the war. A description of the power service building repair shops and equipment is covered later in this chapter. An exterior view of this building is shown in figure 303.

TABLE 14.—*Machine shop equipment data*

Project	Engine lathe (inches) [1]	Bench lathe (inches)	Shaper (inches)	Upright drill (inches)	Sensitive drill (inches)	Power hacksaw (inches)	2-wheel grinder (inches)	Tool post grinder (horsepower)	Portable pipe threader (inches)	Forge (type)	Anvil (pounds)	Arbor press (tons)	Shop area (square feet)	Work benches (No.)	Remarks
Norris	18 by 120	10 by 34	24		13	9 by 9	10	½	¼ to 2		170	7½	1,245	2	
Wheeler	14 by 124	10 by 34	24	30	13	6 by 6	12	([8])	½ to 4		250		1,672	2	
Pickwick	18 by 168	9 by 34	24	30	10	9 by 9	12		½ to 12	Stationary oil fired.	170	7½	1,230	2	
Guntersville	18 by 120	9 by 34	24	30	10	9 by 9	12	½	½ to 8	do	170	7½	1,314	3	
Chickamauga	20 by 120	9 by 34	24	30	10	9 by 9	12	½	½ to 8	do	170	7½	1,000	1	
Hiwassee	20 by 128	9 by 34	24	30	16	9 by 9	12	½	½ to 8	Portable rivet.	170	7½	1,100	1	
Watts Bar [2]		10 by 34			10		10		½ to 6				900	2	Serviced by erection bay crane.
Cherokee	18 by 180	10 by 34	24	30	10	8¼ by 9¾	12	½	½ to 8	Portable rivet.	180	7½	1,225	2	
Douglas	18 by 180	10 by 34	24	30	10	8¼ by 9¾	12	½	½ to 8	do	175	7½	1,225	2	
Ocoee No. 3 [3]		10 by 34			15	8¼ by 9¾	12		½ to 8			7½	560	1	
Apalachia [3]		10 by 34			15	8¼ by 9¾	12		½ to 8				1,180	2	
Fort Loudoun	20 by 128	10 by 34	24	30	10	8¼ by 9¾	12	½	½ to 8	Portable rivet.	175	7½	1,280	3	
Kentucky	20 by 128	10 by 34	24	30	10	8¼ by 9¾	12	½	½ to 8	do	175	7½	1,970	3	
Fontana	20 by 126	10 by 36	25	30	17	8¼ by 9¾	12	½	½ to 8	Stationary coal fired.	400	7½	1,050	3	
Watauga [4]	20 by 124	10 by 34	24	30	10	8¼ by 9¾	12	½	½ to 8	Portable rivet.	175	5	1,630	2	
South Holston [5]		10 by 32			15	10 by 10	12		½ to 8				1,080	1	Serviced by powerhouse crane.
Boone [5]		10 by 36			15	[6] 10 by 18	12		½ to 8			3	650	1	
Fort Patrick Henry [5]		10 by 36			15	[6] 10 by 18	12		½ to 8			3	600	1	Serviced by powerhouse crane.
Chatuge [3]					10		7				170		120	1	
Nottely [3]					10		7				198		240	1	
Wilson	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	([7])	

[1] Most lathes are provided with raising blocks and spare belts to permit increasing swing overbed to 24".
[2] Major repairs to be made at Watts Bar Steam Plant shop.
[3] Major repairs to be made at Hiwassee Hydro Plant shop.
[4] This shop also handles repairs for Wilbur Hydro plant.
[5] Major repairs to be made at Watauga Hydro Plant and John Sevier Steam Plant shops.
[6] Metal-cutting band saw capacity 10" round-18" rectangular flat.
[7] Original shop equipment installed in Utility Building transferred to Reservation Power Service Building shops.
[8] Field constructed.

This text does not include a description of the shop facilities installed in the steam plants, except to say that these fully equipped shops have greatly aided in making hydro plant major repairs and have increased the overall ability and efficiency of TVA in maintaining its power system.

LOCATION AND SPACE REQUIREMENTS

In general, the machine shop and tool room of a hydro plant is adjacent to the generator room, in or near the main erection area. At Fort Patrick Henry and South Holston the shop equipment is located at the end of the generator room proper and is serviced by the powerhouse crane. At most of the other plants a separate room is provided for the shop facilities. At projects having fully equipped machine shops the floor space required varies from 1,000 to 1,900 square feet, depending upon the equipment arrangement and to some extent upon the amount of space conveniently available. A view of a typical large shop is shown in figure 304. The equipment arrangement for the larger shops is shown in plate 6, page 218. The small type shop such as the one at Apalachia is shown in figure 305.

EQUIPMENT PROVIDED

The actual equipment required and provided in each plant is closely coordinated with the Division of Power Operations. Equipment for the earlier designed projects was purchased in accordance with TVA Standard Specification No. M–64. This specification was carefully developed to enable the purchase of machinery which would meet TVA requirements and at the same time be a standard product of several manufacturers. Minor revisions were made to these specifications throughout the years to enable additional manufacturers to bid on the equipment and to incorporate latest design improvements. During World War II, these specifications required considerable modification to conform to governmental restrictions

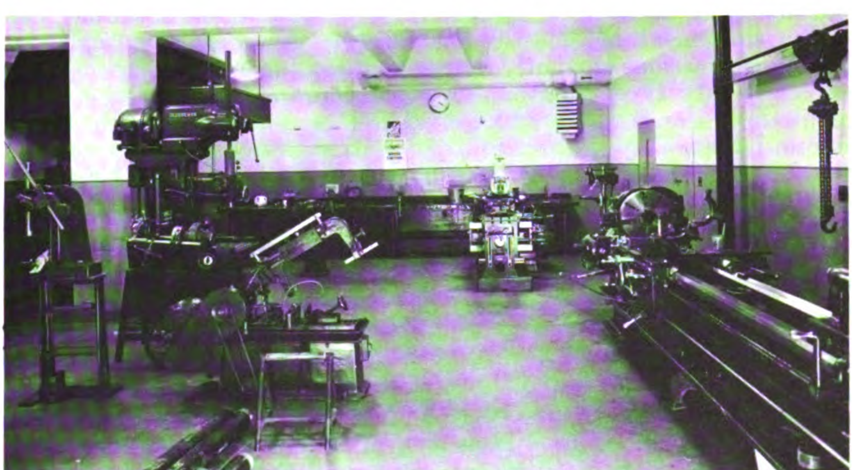


FIGURE 304.—*Typical large hydro machine shop—Guntersville.*

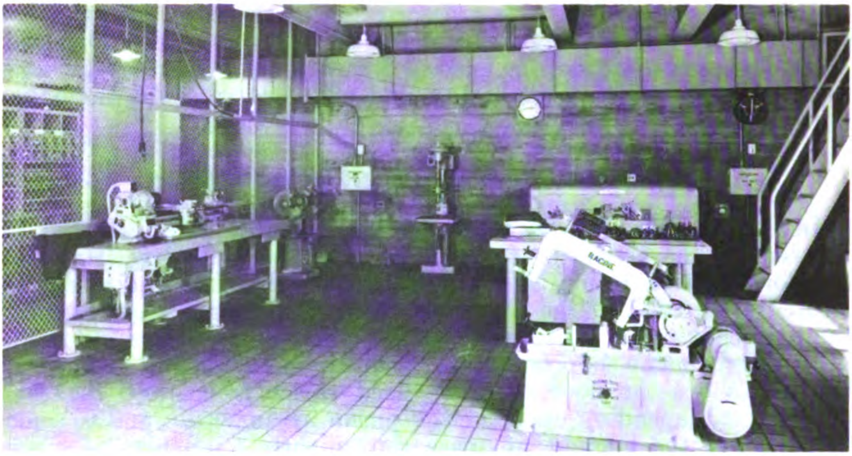


FIGURE 305.—*Typical small hydro machine shop—Apalachia.*

concerning the design and construction of machine tools. It was also necessary to defer installation of some of the larger machines such as lathes and large drill presses during this period due to governmental regulations concerning their purchase. During that period, machines purchased by TVA's Construction Plant Branch for construction of the dam and power plant were utilized to the fullest extent by transferring them to the permanent powerhouse machine shop at the end of the construction work. A few of these transferred machine tools have had to be replaced with newly purchased equipment.

All machines have individual electric motors for 440-volt, 3 phase, 60-cycle current, with the exception of some of the smaller machines, which are provided with 110-volt, single-phase, 60-cycle motors. Motor starting devices are generally mounted on the machines but in some cases are separately mounted adjacent to the machine.

The equipment hereinafter described is in accordance with the latest specifications currently in use. All equipment is of the medium or heavy-duty type required for general precision work where the requirement for accuracy is high. The larger machines, such as the engine lathes, shapers, and upright drill presses were inspected by the TVA Inspection and Testing Branch at the manufacturers' plants prior to shipment to the project. Smaller machines were inspected by the TVA construction forces upon receipt at the project.

Engine lathe

The engine lathe (at right in figures 304 and 306) is of the quick-change, geared-head type. It is furnished complete with housed driving motor, motor control, electric wiring, and accessories as hereinafter described, and meeting ASA B5.16 Accuracy of Engine Lathes Standard. The dimensions, adjustment limits, and other characteristics of the equipment are specified to be approximately as follows:

Swing over bed (inches)	20
Swing over lower slide of compound rest (inches)	12
Distance between centers, tailstock flush (inches)	144
Size of hole in spindle (inches)	1¾
Spindle speeds forward	12
Spindle speeds reverse	12
Number of feed changes	48
Number of thread changes	48
Tailstock spindle traverse (inches)	9
Diameter of tailstock spindle (inches)	3
Cutting tool, size (inches)	¾ and 1⅝

Headstock.—Provision is made for not less than 12 forward spindle speeds and 12 reverse spindle speeds. Speed changes are through gears and are controlled by levers on the front of or adjacent to the headstock and within easy access of the operator. Reverse spindle speeds obtained by means of a reversible motor are not acceptable. An index plate illustrating the position of each lever for any desired speed is mounted close to the levers. A neutral position is provided for the speed change levers, disengaging the spindle drive and permitting free rotation of the spindle by hand. All gears have cut teeth. The bore of the gears is concentric with the pitch line, and the backlash is specified to be not more than 0.005 inch. The shafts for sliding gears have multiple integral keys. Special care is taken to provide adequate spindle bearings. Spindle bearings and clutch bearings are either the ball or roller type. The spindle is taper bored to take a Morse taper center. Automatic lubrication is provided for all change gears and principal bearings.

Tailstock.—The tailstock has a setover adjustment of not less than one-half inch on each side of the centerline, and is designed to permit setting the compound rest parallel with the bed. The tailstock spindle has a Morse taper hole.

Carriage.—Power crossfeed and power longitudinal feed are provided. A lead screw and a feed rod independently operated, or a

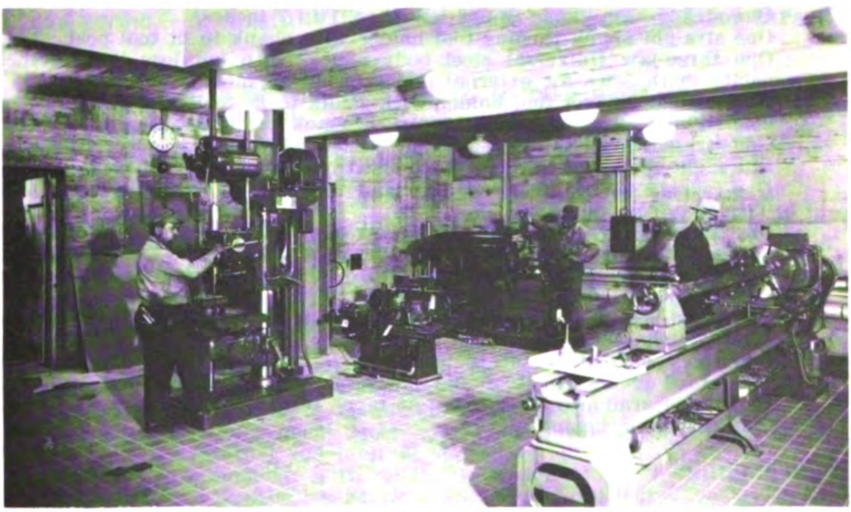


FIGURE 306.—*Machine shop—Hiwassee.*

combined lead screw and feed rod, are furnished and provision is made so that both threading and feeding devices cannot be engaged simultaneously. The lead screw has the threads accurately chased. Controls for starting and stopping the power feeds and for feeding by hand are mounted on the carriage apron. The carriage has a clamping arrangement to fasten it to the bed wherever desired. The carriage also has adjustable gibs for maintaining proper contact with the bedways and felt-lined wipers to keep ways clean. The apron has bearings at both front and rear for all shafts. A compound rest is provided with a top-slide travel of not less than 3½ inches and with a swivel base graduated in degrees from 0 to 180. Micrometer dials on the crossfeed screw and on the compound rest screw are each graduated in thousandths of an inch. The rest is designed so as to permit setting the tool parallel with the longitudinal axis of the lathe.

Bed.—The bed is of sufficient length to take work requiring approximately 144 inches between centers without the tailstock overhanging the end of the bed. The bed is heavily constructed, deep and wide, and is reinforced with heavy cross girths at short intervals. The bed is complete with chip pan.

Drive.—The drive between motor and lathe is through multiple V-type belts and a disc-type clutch. Control of the clutch for starting and stopping the lathe is by means of levers mounted on the movable apron or on the headstock end of the lathe.

Auxiliary equipment.—The following equipment is furnished by the contractor and fitted to the lathe:

One set of necessary wrenches for the lathe.

One large steel faceplate, approximately 19 inches in diameter.

One small steel faceplate, approximately 8 inches in diameter.

One four-jaw independent steel body chuck, with not less than 18-inch capacity, with jaws for external and internal surfaces.

One tool post, complete with collar and wedge.

Two centers, 1 for the headstock and 1 for the tailstock.

One steady rest, capacity not less than 1 to 7 inches.

One straight shank turning tool holder with shank to fit tool post.

One three-jaw Universal steel body chuck, with not less than 18-inch capacity, with jaws for external and internal surfaces.

One left-hand offset tool holder with shank to fit tool post.

One right-hand offset tool holder with shank to fit tool post.

One straight shank cutting-off tool with shank to fit tool post.

One right-hand offset cutting-off tool with shank to fit tool post.

One two-bar boring tool with 15⁄16- and 13⁄16-inch diameter bars and base to fit slot in compound rest.

One right-hand offset shank-threading tool with high-speed cutter for American Standard No. 8 pitch thread series.

One set safety clamp lathe dogs with combined capacities not less than ½ to 4 inches.

One three-jaw drill chuck with arbor to fit taper hole in tailstock spindle 1⁄16- to ¾-inch capacity.

One taper attachment of the carriage type, capable of turning tapers from 0 to 3 inches per foot and not less than 12 inches long, equipped with a scale graduates in degrees of taper inches per foot.

One threading-chasing dial.

Bench lathe

The bench lathe (at left in figure 305) is of the underneath motor, belt-driven, quick-change gear type, complete with motor, motor

control, electric wiring, and accessories as hereinafter described for mounting by TVA on its workbench. The lathe conforms to ASA B5.16 Accuracy of Engine Lathes Standard. The dimensions, adjustment limits, and other characteristics of the equipment are specified to be approximately as follows:

Swing over bed (inches)	10
Swing over lower slide of compound rest (inches)	6½
Distance between centers, tailstock flush (inches)	32
Size of hole in spindle (inches)	1⅜
Spindle speeds	6
Number of feed changes	48
Number of thread changes	48
Tailstock traverse (inches)	2
Cutting tool, size (inches)	⅜ and 13/16

Headstock.—Spindle speed changes are obtained by shifting a belt on the headstock spindle cone and by means of back gears. The spindle is capable of being disengaged from the cone for free rotation by hand. Special care is taken to provide adequate spindle bearings.

Tailstock.—The tailstock is provided with a setover adjustment permitting the spindle of the tailstock to be moved not less than one-half inch either side of centerline.

Carriage.—Manual and power longitudinal and crossfeeds are provided. The carriage has a locking device to secure it to the bed at any point throughout its travel. Adjustable gibs maintain proper contact between the base and top of compound rest. Felt-lined wipers are provided at each end of the saddle. A compound rest has a top slide travel and a swivel base graduated in degrees from 0 to 180 degrees. Micrometer dials on the crossfeed screw and on the compound rest screws are each graduated in thousandths of an inch. The compound rest is designed to permit setting it parallel with the longitudinal axis of the lathe.

Lead screw.—A carefully fitted lead screw is provided for thread cutting.

Bed.—The bed is of sufficient length to take work requiring approximately 32 inches between centers without tailstock overhanging the end of the bed. The bed is heavily constructed, deep, and wide and complete with chip pan.

Drive.—The motor and driving mechanism is designed for mounting below the bench top.

Auxiliary equipment.—The following equipment is furnished by the contractor and fitted to the lathe:

One set of necessary wrenches for the lathe.
One large steel faceplate, manufacturer's standard.
One small steel faceplate, manufacturer's standard.
One four-jaw independent steel body chuck, manufacturer's standard, with jaws for external and internal surfaces.
One tool post, complete with collar and wedge.
Two centers, 1 for the headstock and 1 for the tailstock.
One three-jaw Universal steel body chuck, manufacturer's standard, with jaws for external and internal surfaces.

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One steady rest, manufacturer's standard.
One straight shank turning tool holder with shank to fit tool post.
One left-hand offset tool holder with shank to fit tool post.
One right-hand offset tool holder with shank to fit tool post.
One straight shank cutting-off tool with shank to fit tool post.
One two-bar boring tool with 15/16- and 13/16-inch diameter bars and base to fit slot in compound rest.
One set safety clamp lathe dogs with combined capacities not less than 1/2 to 4 inches.
One three-jaw drill chuck with arbor to fit taper hole in tailstock spindle 1/16- to 3/4-inch capacity.
One taper attachment of the carriage type, capable of turning tapers from 0 to 3 inches per foot and not less than 12 inches long. It is equipped with a scale graduated in degrees of taper inches per foot.
One thread-chasing dial.

Shaper

The 24-inch shaper (center of figure 307) is of the electric motor-driven, selective-gear type, and is complete with motor, motor control, electric wiring, and accessories as hereinafter described.

The dimensions, adjustment limits, and other characteristics of the shaper are specified to be approximately as follows:

Length of table top (inches)	18
Width of table top (inches)	15
Extreme distance, table to ram (inches)	12
Horizontal travel of table (inches)	24
Vertical travel of table (inches)	12
Number of crossfeeds	10
Range of crossfeeds (inches)	.01 to .14
Length of vise jaws (inches)	13
Depth of vise jaws (inches)	3
Extreme vise jaw opening (inches)	15
Length of ram bearing in column (inches)	36
Width of ram bearing in column (inches)	12
Number of ram speeds	8
Extreme length of stroke (inches)	24
Range of cutting strokes per minute:	
From	8
To	95
Extreme vertical travel of toolhead (inches)	8
Size of tool shank (inches)	7/8 by 17/8

Base.—The base is of heavy, rigid design, and includes an extension for table support.

Column.—The column is of ribbed box construction, with reinforced, hard, close-grained, chilled ram ways. An adjustable clamp and gib are provided for compensating for wear in the ram guides and ways.

Crossrail.—The crossrail is of ribbed box construction provided with large diameter stationary elevating screw, a ball- or roller-thrust-bearing equipped elevating nut arranged for convenience.

Table.—A table of rigid box section is the universal revolving type with tilting top. The top and sides of the table have horizontal T-slots machined from the solid. Connection of the table to the crossrail is of rigid construction, and a screw-adjusted full-length taper gib maintains the alinement of the table and crossrail. An adjustable table support of sturdy construction is provided.

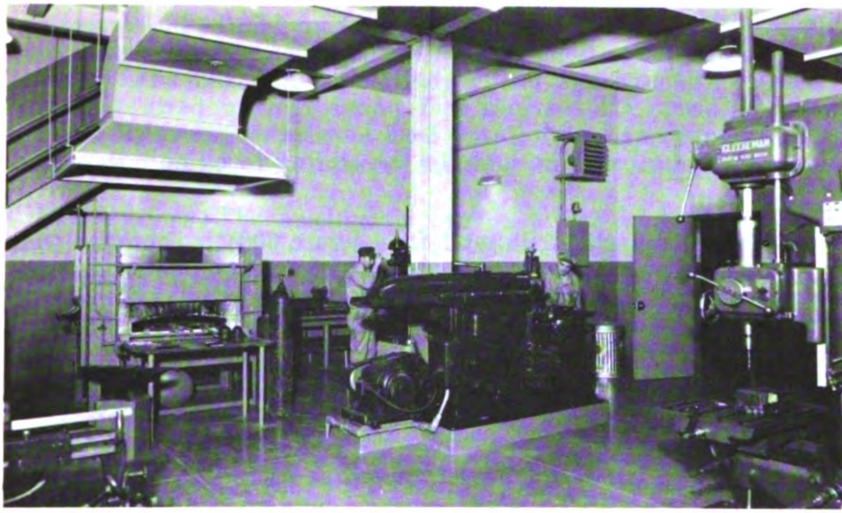


FIGURE 307.—*Machine shop—Chickamauga.*

Crossfeed.—The crossfeed has an adjustable automatic mechanical power feed in both directions, with an easily readable scale or dial. Provision is also made for hand operation of the crossfeed.

Vise.—A substantial double-screw vise and swivel base graduated in degrees is provided.

Ram.—The ram is the V-type, and of ribbed box construction, with wide guides. The length of stroke is adjustable both while the machine is running and while it is at rest. A scale indicates the length of stroke.

Ram toolhead.—The toolhead is arranged to swivel not less than 60 degrees each side of the vertical and clamps in any desired position. The head is graduated in degrees to indicate the angular position. The toolslide has vertical adjustment by means of a large diameter, handle-operated screw, with arrangement for clamping in any desired position. The screw is fitted with a micrometer dial graduated in thousandths of an inch.

Drive.—The drive from the motor is by means of a multiple V-belt, of ample capacity and properly enclosed. Provision is made for conveniently adjusting belt tension. A clutch of the multiple-disc type, or equal, and a suitable brake are provided.

Gearing.—All gearing has teeth cut from solid blanks. All pinions and all gears, except the bull wheel gear, are of forged steel heat-treated, and the bull wheel gear is of annealed cast steel or high quality semisteel. The back gearing is through helical gears. The selective speed gears are spur-tooth, sliding engagement type. The gear box forms an oiltight enclosure for all gears, so that the gears will run in a bath of oil.

Bearings.—All shaft bearings except those for the bull wheel are of the ball or roller type, of ample capacity to withstand the loads imposed. The bearings for the bull wheel hub and wrist pin are bronze bushed. All bearings and power moving parts are automatically lubricated with force feed lubrication provided for the column and ram bearings, and for the sliding block and ways.

Upright drill

The 30-inch upright drill (at left in figure 306) is complete with constant-speed motor drive, speed-changing gears, motor control, electric wiring, and accessories as hereinafter described. The dimensions and operating range of the drill are specified to be approximately as follows:

Lower column to center of spindle (inches)	14½
Base to spindle, upper limit (inches)	48
Base to spindle, lower limit (inches)	18
Base height (inches)	5½
Table working surface area (square inches)	472
Table traverse, vertical (inches)	15
Spindle taper, Morse No.	4
Spindle speeds	12
Lowest spindle speed, revolutions per minute	50
Highest spindle speed, revolutions per minute	1,000
Spindle feeds	8

Base.—The base is of ample depth and has T-slots into which bolts may be entered from either end. The base is surrounded by a channel to drain off drilling lubricant to the reservoir.

Column.—The column is accurately ground and well supported by a heavy rear brace.

Sliding head.—The sliding head is fitted to the face of the column, scraped to a suitable bearing. The head is adequately counterbalanced, raised and lowered by a handwheel, or equivalent, through a steel rack and pinion having cut teeth. It has an easily accessible clamping device which holds the head securely in positoin at any point of its travel and serves to relieve the clamping bolts of undue pressure.

Spindle.—The spindle is accurately ground and designed so that thrust is taken on a ball bearing. Means are provided for taking up the wear of the spindle sleeve.

Feeds.—Power feeds are obtained by operation of a single lever with a direct reading index showing the feed in thousandths of an inch per revolution of spindle. The lever is within easy reach of the operator and the feed is so designed that shift may be made while machine is running. A handwheel feed is also provided.

Table arm and table.—A table arm swings around the drill column, with adequate provision for raising and lowering through a rack and pinion and for clamping in any position. A compound table is arranged to swivel in the center of the table arm, swing around the

column, and has micrometer dial adjustment for both horizontal movements. It is so designed that it can be securely clamped in position.

Vertical milling support.—A vertical milling support is used in combination with the compound table for milling and profiling.

Depth gage.—The machine is provided with a depth gage and automatic trip that is accurate and positive and so arranged that it can be set to a graduated scale to trip the power feed at any desired depth in the entire length of the travel. A safety trip operates at the limit of traverse.

Drive and speed box.—The motor is connected to the shaft of the speed box through a suitable gear drive or gear and clutch drive. All gears have cut teeth, and are enclosed in an oiltight casing and run in oil.

Cutting lubricant system.—A system for the storage and transmission of cutting lubricant is complete with storage reservoir, pump, pump drive, piping, and fittings.

Chuck.—A Jacobs No. 3A chuck, or equal with No. 3 Morse taper shank and arbor to fit drill spindle is furnished.

Sensitive drill

The drill (in far left corner of figure 308) is of the single-spindle, sensitive, stationary head, floor or bench type, complete with housed driving motor, motor control, electric wiring, and accessories as hereinafter described. The dimensions, adjustment limits, and other characteristics of the equipment are approximately as follows:

	Floor type	*Bench type*
Drills to center of circle (inches)	15	10
Spindle speeds (No.)	4	4
Spindle diameter (inches)	5/8	5/8
Spindle travel (inches)	4	3
Chuck capacity (inches)	1/2	1/2
Diameter of column (inches)	2 3/4	2 1/4
Working surface of table (inches)	10 by 12	8 by 8
Morse taper adapter number	1	1

Floor type drills are fitted with foot feed control, table raising mechanism and a hand-key-operated, self-tightening drill chuck having a capacity for 0- to 1/2-inch straight shank drill. Bench-type drills are equipped with a 3-conductor, 15-foot long electrical supply cord, one conductor being used for grounding.

Metal cutting saws

Most of the earlier designed plants were provided with power-driven hacksaws of the reciprocating type (just left of center in figure 304 and at right in figure 305). At the recently designed plants, horizontal high speed band type saws have been purchased for metal cutting. The following descriptions cover both types of saws.

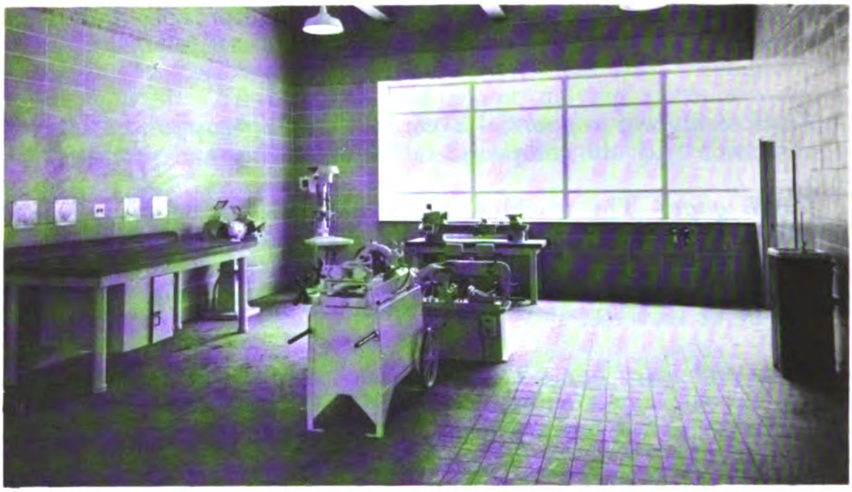


FIGURE 308.—*Machine shop—Ocoee No. 3.*

Power hacksaw.—The power hacksaw is of the high speed, motor-driven, reciprocating, metal sawing type, having approximately the following characteristics:

Size of work (inches)	8 by 9
Blade length (inches)	14 to 17
Extreme stroke length (inches)	6
Number of speed changes	3
Range of speeds (strokes per minute)	60 to 120

The base is of ribbed construction housing the automatic cooling equipment, which includes a positive action circulating pump and a piping system for distributing liquid to the blade for cooling.

The depth of the cut is adjustable and controlled by a gravity feed pressure, with pressure on the blade determined by location of the weight on the saw frame, or by a positive progressive screw feed. An automatic lifting device raises the blade and prevents dragging on the return or noncutting stroke. This lifting device operates mechanically or hydraulically, and the amount of clearance is adjustable. Provision is made to prevent the saw from dropping on the work when the machine is started; this device is adjustable so that thin materials may be sawed without injury to the saw. A quick-acting swivel vise is furnished.

Substantial sliding gears for not less than 3-speed transmission are furnished, which will allow the changing of speeds during operation, with drive clutch for the starting or stopping of motor during operation. The drive is by steel roller chain, or V-belt, or gears from a motor mounted on a solid bracket bolted to rear of machine base.

Horizontal bandsaw.—These saws are high-speed bandsaw metal-cutting type, motor-driven, complete with wet-cutting system, motor, and controls, having approximately the following characteristics:

Capacity:	
Flat, width (inches)	20
Round, diameter (inches)	8
Swivel of vise (degrees)	45
Blade size	¾ by 0.032
Height to top of bed (inches)	24
Width of bed (inches)	9
Minimum speeds (No.)	3

The saw is supported on cast-iron legs, with cast-iron table and metal pan and pump for wet-cutting system. Casters are not required for the base. The depth of cut is adjustable and is controlled mechanically or by oil cushion. A quick-acting, 45-degree, swivel vise is also furnished. The saw is equipped with three or more speeds.

Accessory equipment includes at least six blades of the size for general purpose sawing and each machine is furnished with two saw stock stands. These stands are cast iron, adjustable up to not less than 39 inches and provided with roller top.

Grinders

Pedestal and bench.—Grinders (at end of workbench just left of center in figure 308) are of the two-wheel, direct-connected, motor-driven, pedestal or bench type, for general purpose grinding of all kinds, complete with motor, motor control, and electric wiring. They are suitable for wheels up to and including 12-inch diameter by 2-inch face, and have a speed of not less than 1,750 revolutions per minute.

Adjustable toolrests, fully enclosed, safety-type wheel guards, and shatterproof glass eye shields are provided. Pedestal grinders are of heavy box construction and are fitted with a utility shelf and water cup.

Toolpost.—The toolpost grinder is electric motor driven designed for use with the engine lathe and shaper. It is furnished complete according to the following approximate specifications:

Length of internal grinding attachment (inches)	4
Wheel (revolutions per minute)	3,400
Size of external grinding wheels (inches)	8 by ¾ by ⅝
Size of internal grinding wheels (inches)	¼ by ¼ by ¼
External wheels	1 Fine 1 Medium 1 Coarse
Internal wheels	1 Fine 1 Medium 1 Coarse

Portable pipe threader

The pipe-threading machine (in foreground, fig. 308) is the portable, motor-driven type, adapted for cutting and threading pipe and nipples and for threading bolts. This machine is complete with motor, motor control, electric wiring, and accessory equipment as described and listed below:

Capacity:	
Pipe cutting and threading (inches)	½ to 2, inclusive
Nipple cutting and threading (inches)	½ to 2, inclusive
Bolt threading (inches)	⅜ to 1½, inclusive
Accessories:	
Geared adjustable threading devices, capacity (inches)	2½ to 8, inclusive
Geared pipe-cutting devices, capacity (inches)	2½ to 8, inclusive

Cutter head, die heads, and dies.—The machine is provided with a cutter head equipped with removable cutter blades which are fed by a handwheel. A gage is furnished for each setting of blades. Die heads and dies of the quick-opening type are provided as necessary. There are one complete set of pipe dies for right-hand American Standard taper pipe threads and one complete set of bolt dies for right-hand American Standard coarse-thread series. A cone-type fluted reamer is mounted on an arm of the machine so as to swing conveniently into and out of working position. A heavy three-jaw Universal geared chuck and nipple chuck are also furnished. An oil system of approved type furnishes a steady flow of lubricant to the work.

Steel stand.—The machine is mounted on a portable steel stand equipped with rubber-tired wheels. The stand is enclosed, and space is provided for storage of die heads. Wheels are so arranged that they may be disengaged to permit the stand to be supported on the four legs. An outboard pipe support is furnished.

Geared adjustable threading devices.—Geared adjustable threading devices are furnished, with capacities for 2½-, 3-, 4-, 5-, 6-, and 8-inch pipe. Ratchet handles, wrenches, and dies are furnished with each threading device. Dies have right-hand American Standard taper pipe thread.

Geared pipe-cutting devices.—Geared pipe-cutting devices are furnished with capacity for 2½-, 3-, 4-, 5-, 6-, and 8-inch pipe. Ratchet handles, wrenches, and cutter knives are furnished with each cutting device.

Drive shaft.—The above threading and cutting devices are designed for operation by the ratchet handles or by a power drive shaft. A drive shaft designed for connection to the pipe-threading machine is furnished for operating the above threading and cutting devices.

Forge and accessories

In some of the earlier designed plants stationary-type oil-burning forges were purchased and installed (at left in fig. 307). At other plants coal-burning stationary forges were transferred from the construction shops to permanent use in the powerhouse machine shop. Operating experience indicated that this larger stationary type of forging furnace was not required. For the later designed plants portable type coal burning rivet forges were provided. This type of forge has a hearth diameter of approximately 18 inches, is hand operated through ball bearings, and comes equipped with an enclosed geared 9-inch blower fan and a windshield hood. The blower and forge are supported on a substantial stand, with the complete unit weighing approximately 150 pounds.

A blacksmith's anvil weighing approximately 170 pounds is furnished for use with the forge. Anvils are usually specified to be of wrought-iron forging with the top face of Sheffield steel, carefully tempered to withstand the greatest wear, having a face length of 16 inches, face width of 4 inches and 10-inch bick and table.

A rectangular steel quench tank approximately 2 feet wide by 4 feet long and 2 feet deep is furnished and located near the forge and anvil. A forced ventilation retractable exhaust hood is mounted over the forge, as shown in figure 291, page 594.

Arbor press

Most shops are provided with a hand-operated, ratchet-type, single-leverage arbor press (at left in fig. 304) having a capacity ranging from 3 to 7½ tons. Pedestal mounted presses have a cast-iron pot. Some presses are designed for bench mounting. Three-ton presses are specified for a maximum of 12-inch diameter work with 1¾-inch arbor and 11-inch capacity over the table.

Motors, controls, and wiring

The foregoing described shop machines are furnished with motors, controls, and wiring conforming to ASA Standard C74. Where ASA C74 refers to other standards, those in effect on date of issue of invitation for bids apply. Motors and controls are mounted where they are accessible for maintenance, convenient for operation, and protected from injury.

Motors are squirrel cage, full voltage start, with class A insulation. They are dripproof, 50° centigrade rise, or if mounted on machine so as to be adequately protected from water, coolant, dirt, and metal chips, they may be open frame, 40° centigrade rise. They have appropriate speed, torque, and capacity characteristics to adequately meet all starting and continuous operating requirements within the operating range of the machine. Windings are resistive to moisture, oil, and abrasive particles. Bearings are ball or roller type with grease seal or other adequate means for retaining the correct amount of lubricant without dripping.

The control equipment usually consists of (1) a magnetically operated contactor with undervoltage and thermal overload protection, enclosed in a steel control cabinet and (2) a heavy-duty, enclosed, start-stop pushbutton. The control cabinet has terminals for and is arranged to receive the incoming power supply circuit. A pushbutton is located on the machine in a position readily accessible to the operator. A separate power supply disconnecting switch is not required.

Wiring on the machine between motors and controls is usually enclosed in metal conduit, neatly arranged, and rigidly attached to the machine frame.

Miscellaneous tools, accessories, and services

Each plant is supplied with a miscellaneous assortment of shop tools and accessories such as chain and ratchet lever hoists, forged

C-clamps, vises, pliers, wrenches, lamp changers, soldering and welding equipment, lubricating guns, machinist straight edges, squares, rules and V-blocks, ladders, warehouse trucks, tarpaulins, and the repair supplies necessary for a machine shop.

Lifting eyebolts are provided in the ceiling above the principal machines for the attachment of chain hoists. Special swinging crane lifts, such as shown at extreme right in figure 304, are sometimes fabricated on the job for use in connection with lathes and larger machines.

Workbenches with cabinets are constructed by TVA in accordance with TVA Standard benches A and B shown in plate 47. Pipe and bar stock storage racks are also built on the job to suit individual shop needs. Standard bins and shelving are purchased for stock storage in the toolrooms.

Electrical service outlets for 440-volt, 3-phase, 60-cycle and 110-volt single phase, 60-cycle alternating current and 250-volt direct current are installed throughout the shop. Compressed air and raw water service hose connection outlets and drinking water coolers are also installed.

CENTRAL REPAIR SHOPS

As mentioned in the introductory remarks of this chapter, the power service building at Wilson Dam Reservation was completed in 1952 to serve as a major repair facility for the TVA power system. This structure is located approximately three-quarters of a mile south of the Wilson Hydro Plant and is a short distance east of the principal highway. Subsequent additions have been made to the original structure to meet the requirements of the expanding power system. The present structure, shown in figure 303, in addition to warehousing, office space, and pole yard storage includes the following completely equipped shops and service facilities:

Main machine shop
Blacksmith structural and metal shop
Paint shop
Welding shop
Metal spray room
Thrust shoe and steam cleaning room
Carpenter shop
Bushing shop
Coil working shop
Transformer repair pit with vacuum drying oven
Lamination washing and storage room
Oil purification facilities
Electric truck and battery charging room

The general arrangement and a complete listing of the machine tools and service equipment in these shops are shown in plates 48 and 49. The larger type of repair operations such as remachining hydro generator thrust bearing runners (fig. 309) and complete rewinding and drying out of the largest of TVA's main power transformers can be handled in these shops. A large electrically heated vacuum drying oven has been provided for the latter operation. Figure 310 shows a view of the main machine shop and fig-

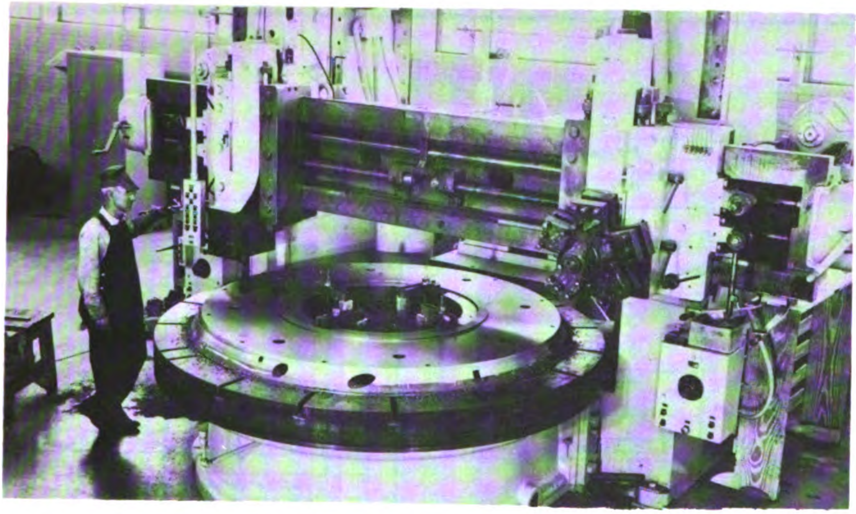
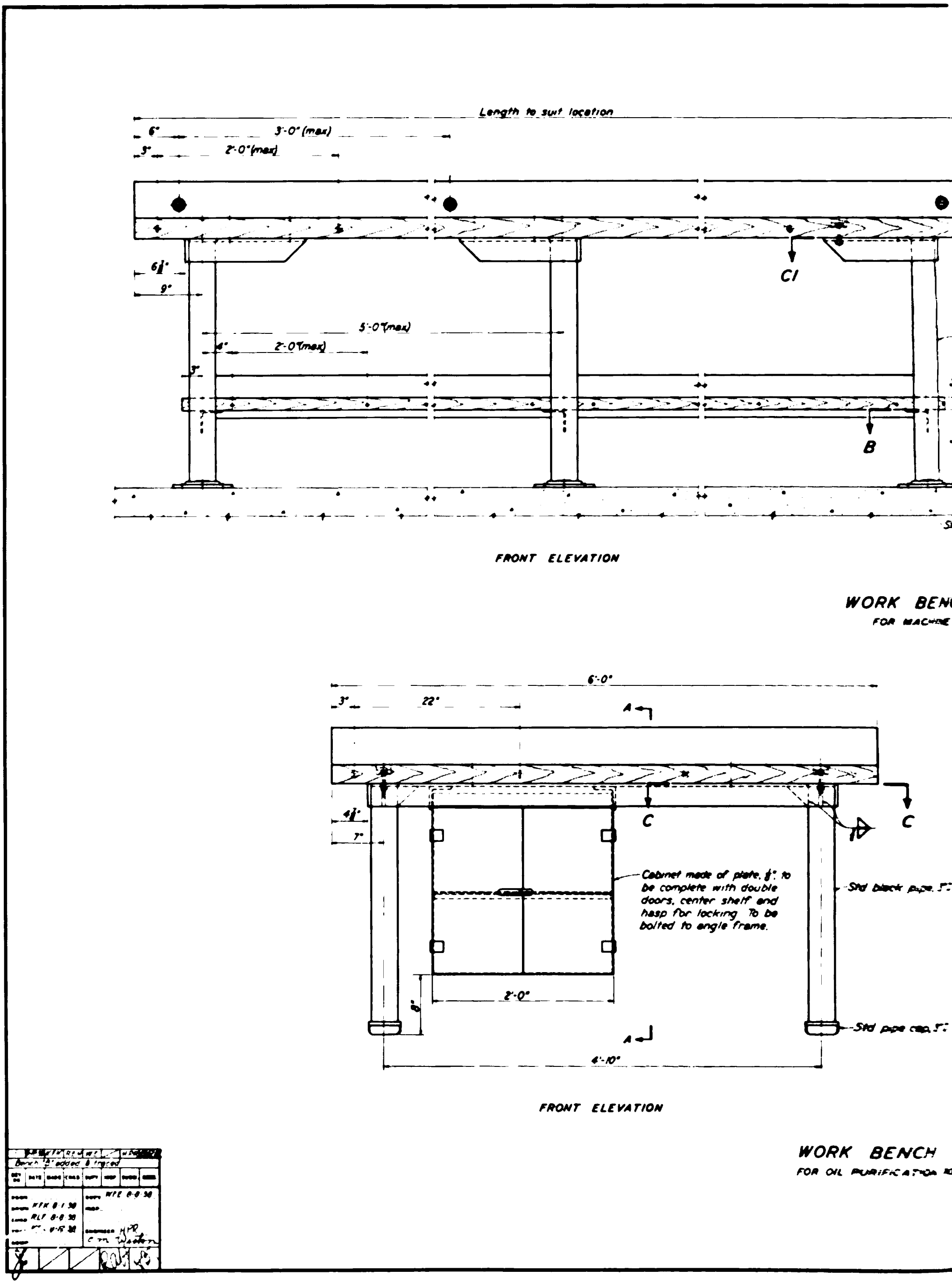
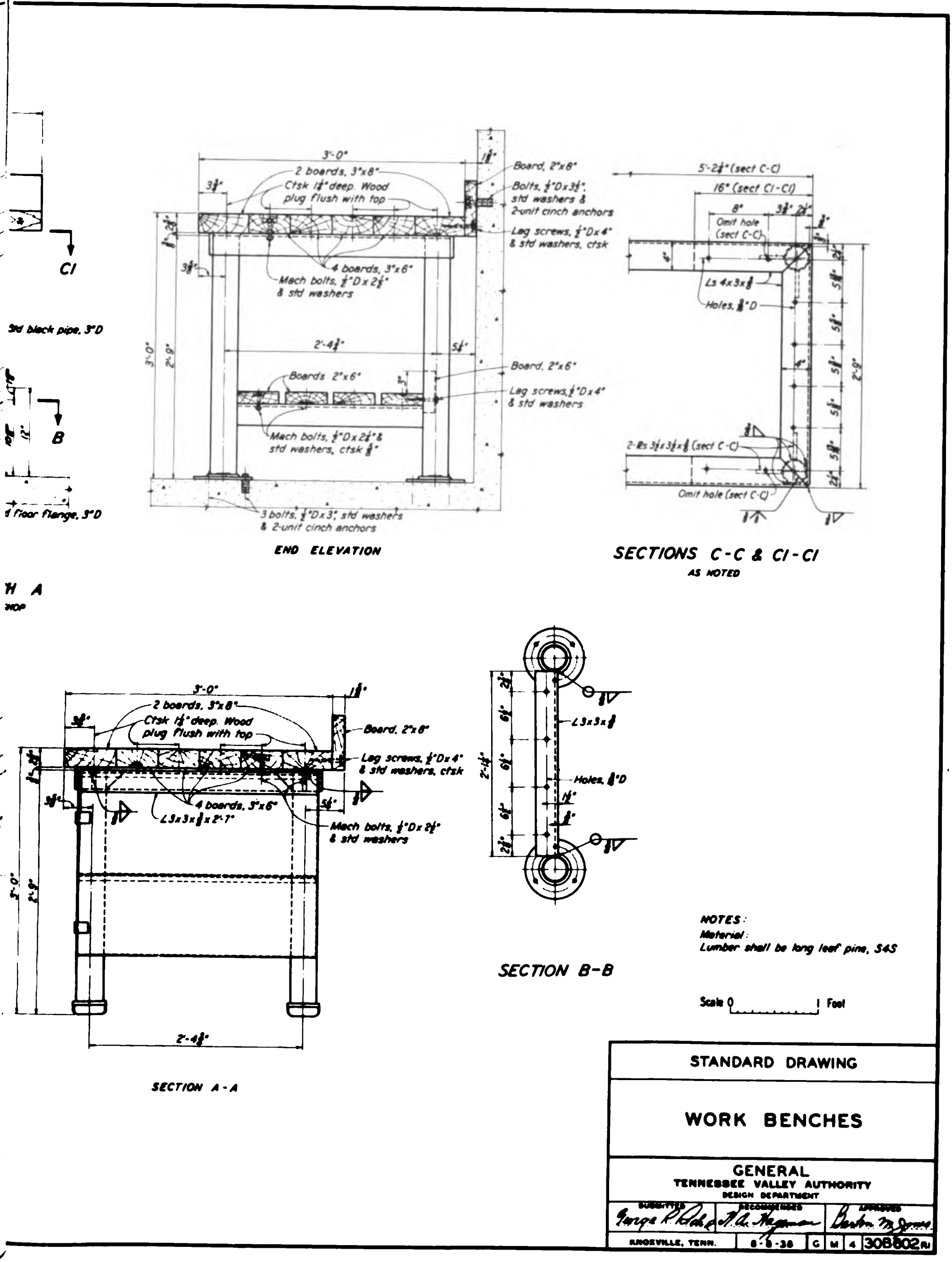
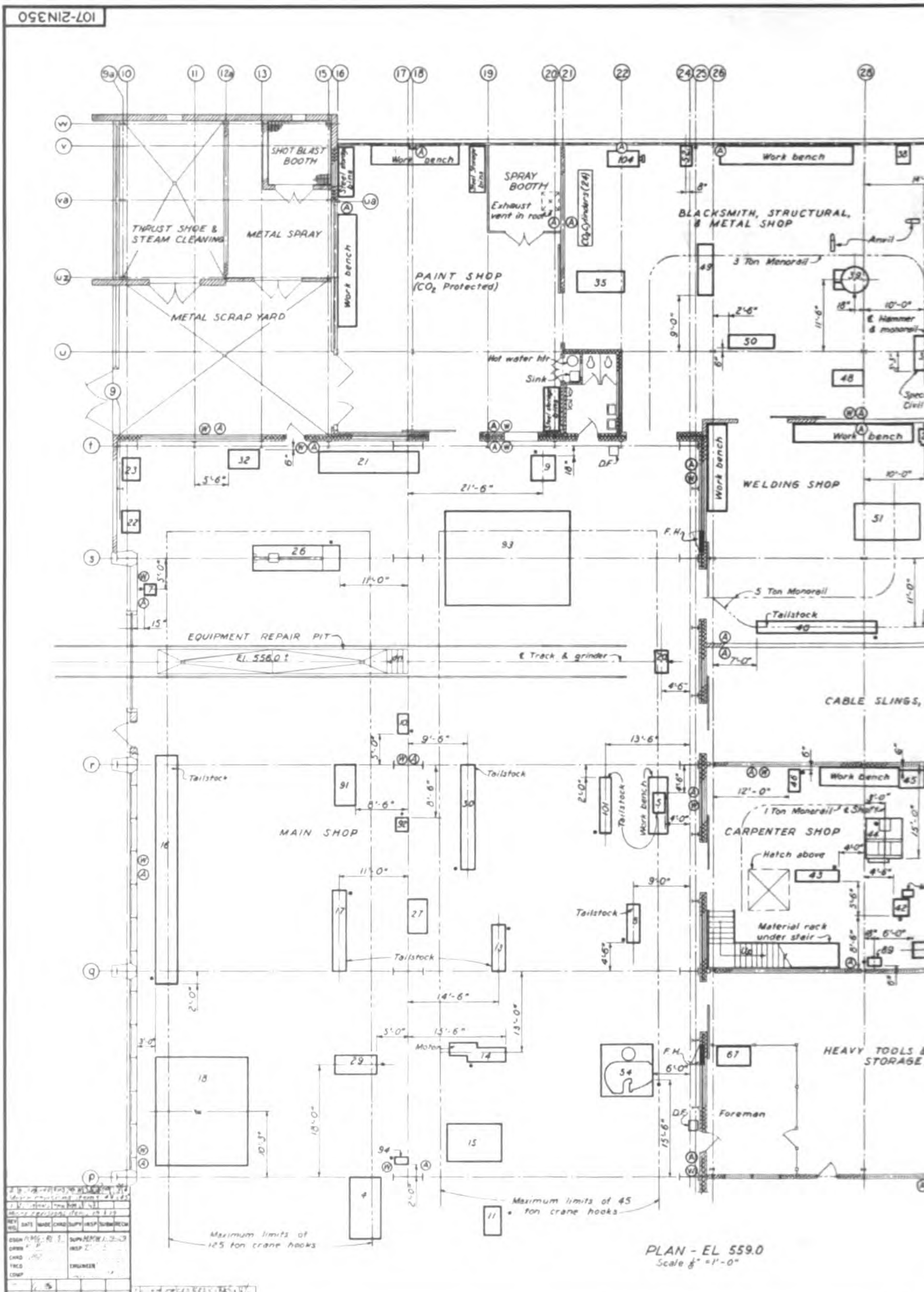


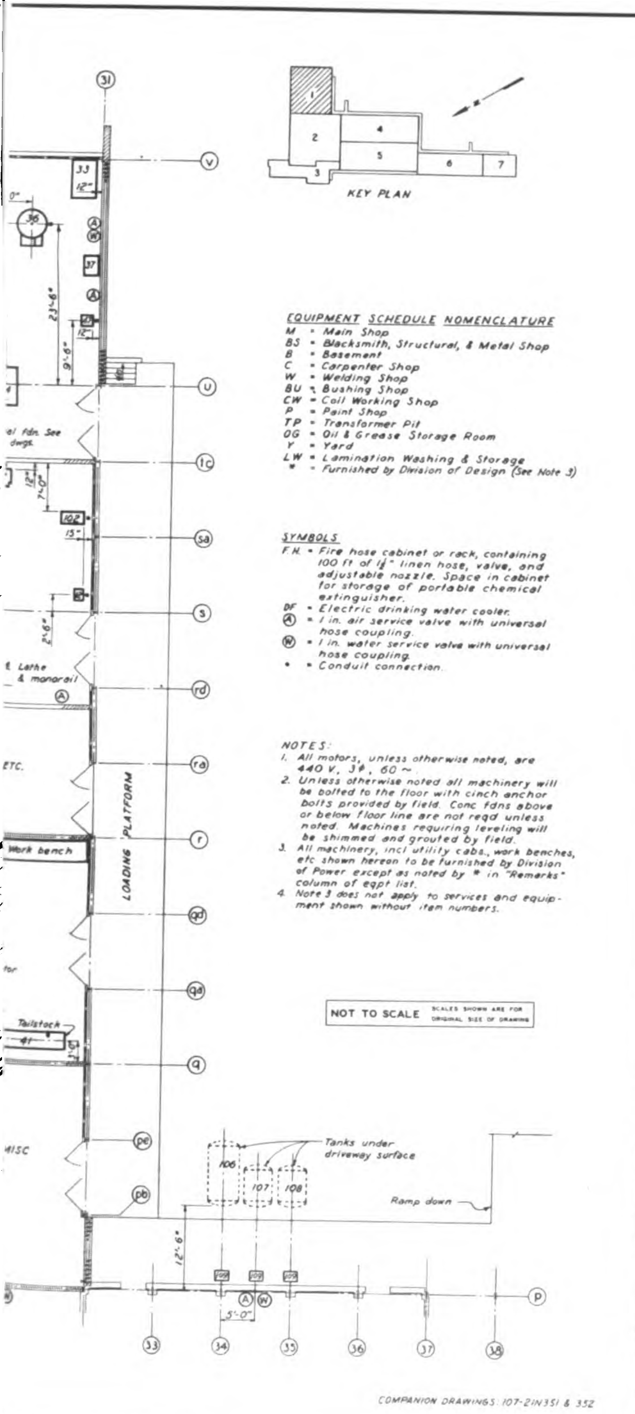
FIGURE 309.—*108-inch vertical boring mill remachining generator thrust bearing runner plate of Watts Bar unit 2—Power Service Building.*

FIGURE 310.—*Main machine shop in Power Service Building—entrances to other shops at left.*


Length to suit location
6"
3'-0" (max)
3"
2'-0" (max)
C1
6½"
9"
5'-0" (max)
4"
2'-0" (max)
3"
B
FRONT ELEVATION
WORK BENC
6'-0"
3"
22"
A
4½"
7"
C
C
Cabinet made of plate, ⅛" to be complete with double doors, center shelf and hasp for locking. To be bolted to angle frame.
Std black pipe
2'-0"
8"
Std pipe cap
4'-10"
FRONT ELEVATION
WORK BENCH


END ELEVATION
SECTIONS C-C & CI-CI
AS NOTED
SECTION B-B
SECTION A-A
2 boards, 3"x8"
4 boards, 3"x6"
Board, 2"x8"
Board, 2"x6"
Boards 2"x6"
Omit hole (sect C-C)
Holes
NOTES:
Material:
Lumber shall be long leaf pine, S4S
Scale 0 1 Feet
STANDARD DRAWING
WORK BENCHES
GENERAL
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE, TENN.


107-21N350
SHOT BLAST BOOTH
THRUST SHOE & STEAM CLEANING
METAL SPRAY
METAL SCRAP YARD
Work bench
SPRAY BOOTH
Exhaust vent in roof
PAINT SHOP (CO_2 Protected)
Hot water htr.
Sink
BLACKSMITH, STRUCTURAL, & METAL SHOP
3 Ton Monorail
Anvil
℄ Hammer & monorail
WELDING SHOP
5 Ton Monorail
Tailstock
EQUIPMENT REPAIR PIT
El. 556.0 ±
℄ Track & grinder
CABLE SLINGS, E
MAIN SHOP
CARPENTER SHOP
1 Ton Monorail
Hatch above
Material rack under stair
HEAVY TOOLS & STORAGE
Foreman
Motor
Maximum limits of 45 ton crane hooks
Maximum limits of 125 ton crane hooks
PLAN - EL 559.0
Scale ⅛" = 1'-0"



EQUIPMENT LIST

ITEM NO.	LOCATION	DESCRIPTION		REMARKS
1	M	Grinder, base type, 2-2"x12" wheels (wet or dry)	3 hp	New
2	W	Grinder, base type, 2-3"x18" wheels	3 hp	Old
3	M	Grinder, base type, for carboloy tools	1 hp	New
4	M	Lathe, 18"x8' (4' between centers) 7" hollow spindle	7½ hp	New
5	M	Lathe, 8"x38" (18" between centers)	½ hp	Old
6	M	Drill press, 20", No. 4 Morse spindle	3 hp	Old
7	M	Universal grinder, cutter type	¾ hp	Old
8	M	Lathe, 12"x4' between centers, special precision, tool makers type	5 hp	New
9	M	Bolt machine, Landis double head, ⅜" to 2"	5 hp	Old
10	M	Power saw, 8" stroke	2 hp	Old
11	M	Milling machine, No. 3A Brown & Sharp	7½ hp	Old
12	W	Grinder, base type, 2-1½"x12" wheels	3 hp	Old
13	M	Lathe, 14"x8½' (5' between centers) Lodge & Shipley	5 hp	Old
14	M	Shaper, 24" stroke, steptoe	5 hp	Old
15	M	Shaper, 36" stroke	15 hp	New
16	M	Lathe, 48"x35' (17' between centers) Taper attach. Gearhead change	40 hp	New
17	M	Lathe, 30" Lodge & Shipley	15 hp	Old
18	M	Boring mill, 9' vertical side & roll head 6' min. under cross rail For voltages see Elec dwgs	75 hp	New
19	M	Planer, 48"x48"x12', open side. For voltages see Elec dwgs.	43 hp	New
20	M	Grinder, base type, 2-2½"x18" wheels (wet type)	5 hp	New
21	M	Pipe bench, 30" wide laminated oak top, steel frame & legs, with pipe vises Nos. 1 & 3		New
22	M	Gas engine test set & misc power tools, portable, provide 110 v. convenience outlet	1 hp	Old
23	M	Gas engine repair tools & misc hand tools		Old
24	B	Air receiver, 200 cu ft (manifolded)	(2 reqd)	* New
25	B	Air compressor, 470 cfm, 100 psi, with aftercooler & press. control eqpt	100 hp (2 reqd)	* New
26	M	Hydraulic press, 200 ton, 6' bet. rails, 10' bet. heads. (Horizontal wheel type)	5 hp	New
27	M	Metal band saw, "Do-All" Model V-36	1½ hp	New
28	M	Drill press, 28", No. 4 Morse taper spindle	5 hp	New
29	M	Drill press, 5' radial, No. 5 Morse taper spindle	10 hp	Old
30	M	Lathe, 18"x16½' (10' bet. centers), Lodge & Shipley	5 hp	Old
31	M	Key seater, No. 3, 2"x15" cap.	3 hp	New
32	M	Mandrel press, 75 ton hydraulic, no elec conns		Old
33	BS	Heating furnace, fuel oil tank mounted on furnace (No pipe conns or vent)		Old
34	BS	Large hammer, 1200 lb pneumatic, 2½" air supply, 3" air discharge thru roof. (Isolated foundation)		Old
35	BS	Punch & shear, Buffalo No. 1½, cap. ⅝" plate 1⅞" round, 1½" square, 4"x4"x½" angles	5 hp	New
36	BS	Blacksmith forge, elec blower, 110 v., 1φ	½ hp	New
37	BS	Tempering furnace, propane gas fire oven approx 12"x12"x5"		New
38	BS	Trip hammer, 100 lb size	3 hp	New
39	BS	Blacksmith forge, elec blower, 110 v., 1φ	½ hp	New
40	W	Gap Lathe	10 hp	Old
41	C	Wood Lathe	5 hp	Old
42	C	Rip saw	5 hp	Old
43	C	Jointer	7½ hp	Old
44	C	Wood planer, 16"	20 hp	New
45	C	Dewalt saw (on bench)	5 hp	New
46	C	Band saw	5 hp	Old
47	BS	Grinder, base type, 2-2"x12" wheels	3 hp	New
48	BS	Face plate, 30"x60" cast steel		New
49	BS	Sheet metal brake, 6'x16 gage cap. hand operated		Old

List cont on Dwg 107-2IN351

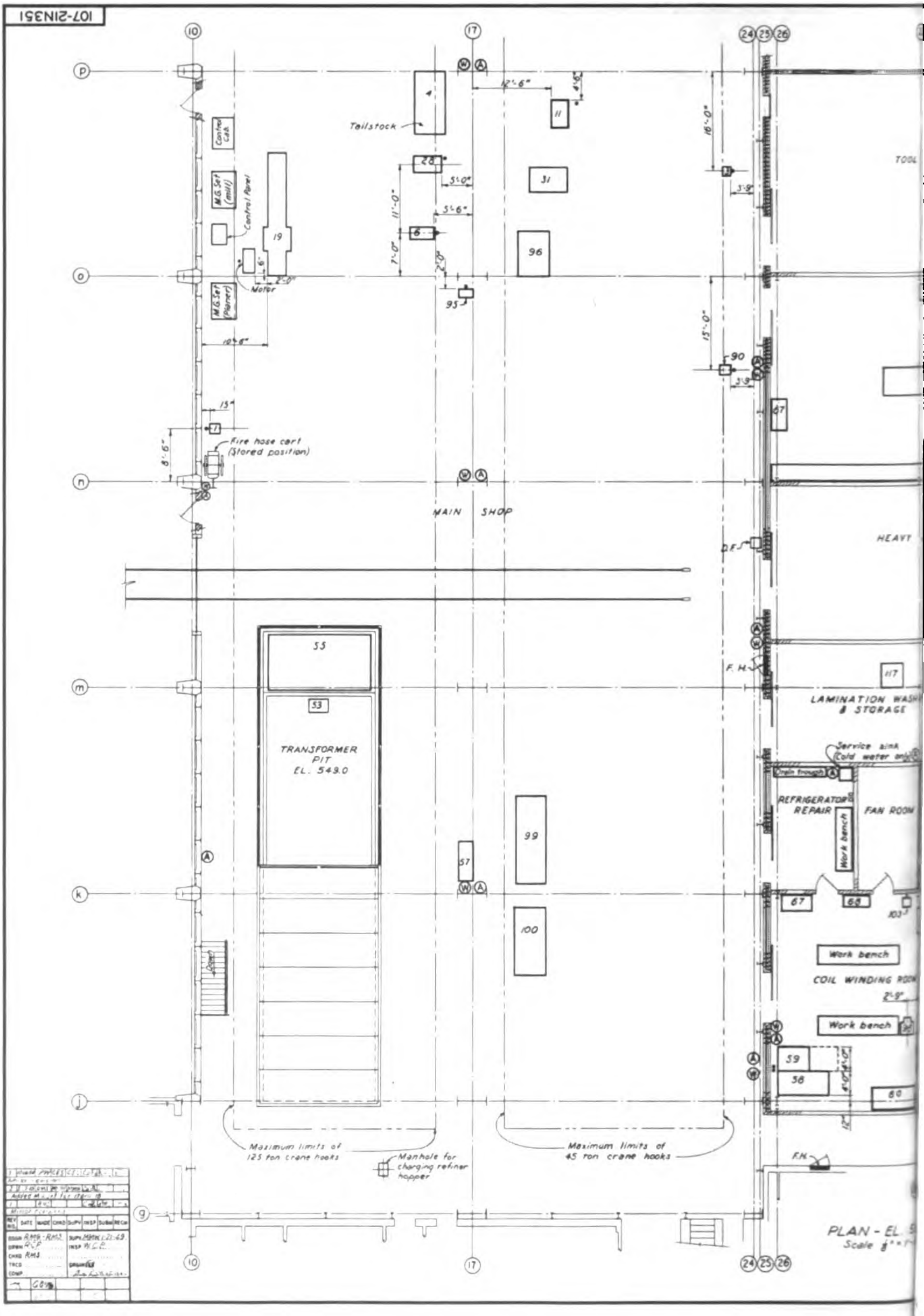
POWER SERVICE BUILDING
BLOCK 1

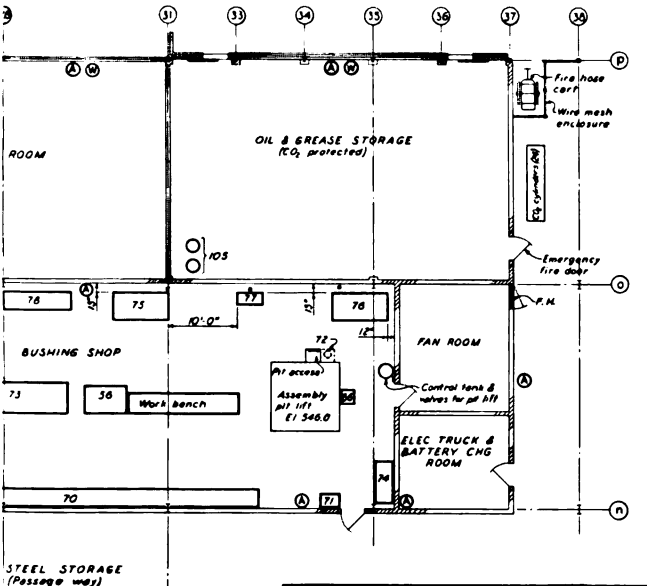
MECHANICAL
GENERAL ARRGT OF MACHINERY
MAIN & MISCELLANEOUS SHOPS-SHEET 1

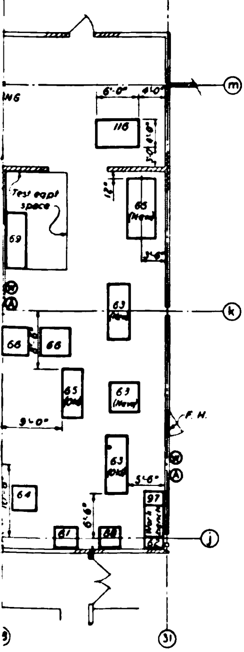
WILSON RESERVATION
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
R.m. Gardner		

KNOXVILLE | 1-24-49 | I | M | 8 | 107-2IN350R3


107-21N351
Tailstock
Control Cab.
M.G. Set (mill)
Control Panel
M.G. Set (Planer)
Motor
Fire hose cart (Stored position)
MAIN SHOP
TRANSFORMER PIT EL. 549.0
Maximum limits of 125 ton crane hooks
Manhole for charging refiner hopper
Maximum limits of 45 ton crane hooks
TOOL
HEAVY
LAMINATION WASH & STORAGE
Service sink Cold water only
Drain trough
REFRIGERATOR REPAIR
FAN ROOM
Work bench
COIL WINDING ROOM
PLAN - EL.
Scale



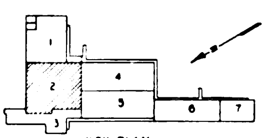


ITEM NO.	LOCATION	DESCRIPTION		REMARKS
50	BS	Shear, sheetmetal, 6'x16 gage cap No elec conn		Old
51	W	Face plate (shop made)		Old
52	BS	Nibbler, Savage, ⅛" sheet cap	2 hp	Old
53	TP	Vacuum pump, 230v, 3Φ	5 hp	New
54	M	Lathe, 36" vertical Bullard boring mill	7½ hp	New
55	TP	Transformer drying tank, 230 v, 3Φ	75 KW	New
56	BU	Gasket cutting table, 4'x6'x3' high		New
57	M	Utility cabinet, steel, 2'x6'x7' high		New
58	CW	Oven, 4'x6'x8' high, 220 v, 3Φ, 60 amp 3" vent pipe thru roof (Reconnect for 440 v)	8 KW	New
59	CW	Oven, 3'x4'x4' high, 220 v, 1Φ, 60 amp 3" vent pipe thru roof (Reconnect for 440 v)	4 KW	New
60	CW	Varnish vat, 4'x8'x3' high, steel		New
61	CW	Arbor press, 50 ton hydraulic, portable		Old
62	CW	Small level wind, 6"x30"	½ hp	New
63	CW	Winding machine, Browning transf & coil winder 220/440 v, 3Φ (3 reqd)	6 hp ea	2-New 1-Old
64	CW	Paper folder, Ideal	½ hp	New
65	CW	Coil formers, Browning (2 reqd) ½" air supply		1-New 1-Old
66	CW	Winding tables, 4'x4'x3' high, steel (2 reqd)		New
67	As noted	Steel desks, 60"x34" std (3 reqd) 1-CW, 1-BU, 1-Foremans office		Old
68	CW	Instrument cabinet, 2'x4'x7' high, steel		New
69	CW	Test bench, 3'x8'x3' high, 600 v. plug type		New
70	BU	Bushing storage rack, wood, 62' long ±		New
71	BU	Brass dip and service sink, 2'x2'x18" deep		*New
72	BU	Drainage sump pump, 36 gpm, 110/220v, 1Φ.	½ hp	*New

EQUIPMENT LIST (Cont)

ITEM NO.	LOCATION	DESCRIPTION		REMARKS
73	BU	Assembly racks, 12' long (2 reqd)		Old
74	BU	Utility cabinet, 2'x6½'x7' high, steel		Old
75	BU	Oven, 4'x8'x6' high, 220 v., 3Φ, 60 amp portable (Reconnect for 440 v.)	10 KW	Old
76	BU	Oven, 4'x8'x4' high, portable (Reconnect for 440 v.)	5 KW	Old
77	BU	Oven, 2'x4'x18" high, 220 v., 1Φ, 60 amp portable (Reconnect for 440 v.)	6 KW	Old
78	BU	Taping machine, 8' long, air operated, ½" air supply, no elec conn		Old
79	B	Oil tank, 1038 gal (for special handling)		*New
80	B	Oil purifier, 1200 gph with centrifuge, htr, filter press, oven deaerator, tanks, pumps, & meter (Equal DeLaval 34)		*New
81	B	Future purifier, same as item 80		*New
82	B	Oil refiner, acid corr complete with pumps, etc. (Crane-Hanan)		*New
83	B	Oil transfer pump, 115 gpm @ 50 psi	7½ hp	*New
84	B	Oil tester (Dielectric)		New
85	B	Utility cabinet, 2'x4'x7' high		New
86	BU	Air hoist, 2 ton, at assembly pit, ½ air supply		Old
87	B	Oil tank, 1038 gal, acid corrected oil		*New
88	CW	Lathe, 8"	5 hp	New
89	C	Belt sander	½ hp	New
90	M	Grinder, wet or dry, 2"x12" wheels	3 hp	New
91	M	Milling machine, No. 5, approx base dimensions 77"x40"	Approx 50 hp	New
92	M	Punch press, 15 ton cap.	½ hp	New
93	M	Assembly & beading plate, 24-30"x60" steel slabs		New
94	M	Drill grinder (Sharpener) small, cap. ⅛" to ½"	1 hp	New
95	M	Drill grinder (Sharpener) large, cap. ½" to 3"	2 hp	New
96	M	Power hack saw, 12" cap	2 hp	New
97	CW	Drill press, bench type, ½" cap.	½ hp	New
98	CW	Band saw, Do-All, 12"	½ hp	New
99	M	Brake, 9' hand-operated		New
100	M	Shear, 9' hand-operated		New
101	M	Lathe, 20" American engine type (To be reconditioned)	7½ hp	Old
102	W	Spot welder	60 KVA	New
103	CW	Grinder, base type, 2-1½"x12" wheels	2 hp	New
104	BS	Portable steam cleaner, kerosene-fired, 120 gph at 75 psi (Stored position shown)		New
105	OG	Hand type barrel pumps (2 reqd)		New
106	As noted	Gasoline storage tank, 1038 gal. West drive, Block 1		*New
107	"	Kerosene storage tank, 502 gal West drive, Block 1		*New
108	"	Varsol storage tank, 502 gal West drive, Block 1		*New
109	"	Elec dispensing pumps for items 106, 107, & 108 F.S. type, 110 v., 1Φ. Loading platform, West drive, Block 1		*New
110	B	Drainage sump pumps, duplex type, float oper, 58 gpm, for bsmt & fan drainage, 110/220 v., 1Φ	½ hp	*New
111	B	H.W. Storage tank, 778 gal., immersion heating elements		*New
112	B	H.W. circulating pump, 110 v., 1Φ, 15 gpm at 5' TDH		*New
113	Y	Oil storage tanks, 12,118 gals. each (8 reqd)		*New
114	Y	Dirty oil transfer pump & metering eqpt, 115 gpm at 33 psi with motor heaters	5 hp	*New
115	Y	Clean oil transfer pump & metering eqpt, 115 gpm at 33 psi with motor heaters	5 hp	*New
116	LW	Degreaser, propane gas htd, ½" water supply 1" water drain		Old
117	LW	Washer, electrically operated, portable, plugs into 110 v. outlet	½ hp	
118				
119	B	Sump tank for transformer pit drainage, 80 gal		*New
120	Y	Spoiled oil tank, 863 gal.		*New
121	B	Sump pump, float operated, 58 gpm, for transf pit drainage, 110/220 v., 1Φ	½ hp	*New

NOT TO SCALE — SCALES SHOWN ARE FOR ORIGINAL SIZE OF DRAWING



KEY PLAN

COMPANION DRAWINGS 107-21N350 & 352

POWER SERVICE BUILDING
BLOCK 2

MECHANICAL
GENERAL ARRGT OF MACHINERY
MAIN & MISCELLANEOUS SHOPS-SHEET 2

WILSON RESERVATION
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
R.M. Gardner	H.J. Petersen	R.A. Monroe

KNOXVILLE	1-24-49	1	M	8	107-21N351 R3

ure 311 shows one of the larger shop machines in operation. Figure 312 shows the complete welding shop in this structure and indicates several types of welding operations which may be performed.

Complete purification facilities are provided for the centrifuging, filtering and acid correction of insulating oil used in transformers, oil circuit breakers, and other electrical switchyard equipment. These facilities are described in chapter 10, "Oil Systems."

Many of the larger machines installed in these shops were obtained by purchase from war surplus and the War Assets Administration. Much of the other equipment was transferred from the Wilson Hydro Plant utility building and other maintenance shops which were to be abandoned by creation of the new service shops.

FIGURE 311.—*25-inch engine lathe turning exciter collector rings for Wilson generator—Power Service Building.*

Figure 312.—*Welding shop in Power Service Building showing acetylene and electric welding.*

Chapter 16

PIPING

Preceding chapters have presented, in some detail, descriptions of the TVA hydro plant mechanical auxiliaries and their related individual piping systems. This chapter outlines some of the more important requirements and essentials for designing the piping systems. It is not intended that this chapter shall represent a comprehensive treatise on powerplant piping, as this subject has been well covered in numerous text books and manuals; however, certain related principles are reviewed which are considered good piping practice. It should be understood that some of the designs and piping materials utilized in the earlier TVA constructed plants have been superseded by later designs employing new types of materials, and it is expected that future designs will incorporate still further improvements as operating experience dictates and new materials and techniques are developed.

In laying out a piping system the designer should strive for simplicity and safety. He should endeavor to visualize the entire plant operation, bearing in mind that while construction costs are affected by design, operating costs are a continuing item where long-term savings may be realized by a slight increase in the initial investment.

A typical hydro plant piping gallery is shown in figure 313.

FLOW DIAGRAMS

The fundamental requirement for any piping system is that it shall be functionally correct. All valves and items of equipment

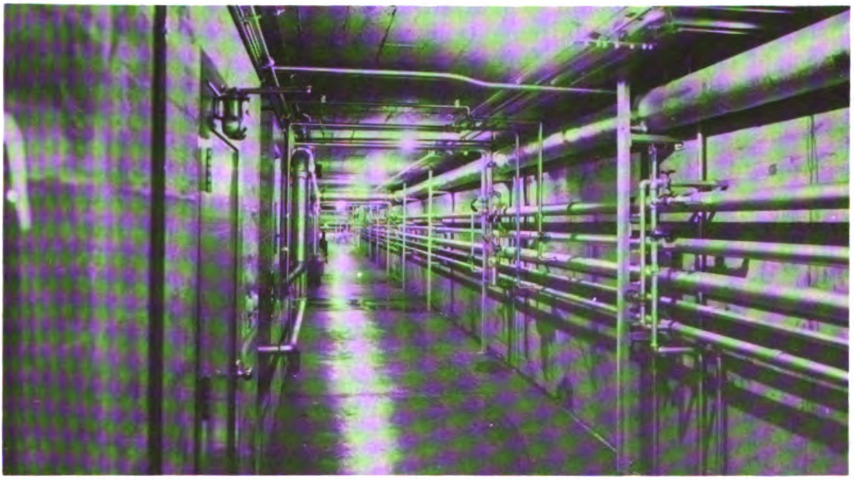


Figure 313.—*Typical piping gallery serving generating units—Chickamauga.*

should be in proper relation to each other so that the system operates in the most efficient manner possible. The best way to obtain this result is by making a valve operation diagram, or what is more commonly known as a flow diagram. Plate 27, page 488, is such a diagram for a governor and lubricating oil system at one of the TVA plants. It will be noted that this diagram outlines the entire system, including all valves, equipment, and machinery. From this it is very easy to check the overall design of the system from a functional standpoint. This diagram, made in sketch form before any drawings are begun, serves as a guide to the designer and draftsman in making the detailed drawings. When made into a drawing it has the further purpose of aiding the field erection forces in the installation of the piping, and finally it enables the operators to visualize the system as a unit which promotes more efficient operation.

Each valve on each system is marked with an aluminum tag describing its function (fig. 314). Tags A, B, and C are attached to the valve handwheels underneath the nut, while tag D is attached to the valve bonnet bolt, to the valve stem, or to the operating chain. In the latest designed plants tag D is used almost exclusively since it can be placed in a location on any valve so that it will always be visible to the operator. Each valve is also numbered according to a standard system, and an experienced operator can tell a valve's relative location in the piping system by its number. The symbols shown on the diagram for the various kinds of valves and items of equipment are standard for the flow diagrams for all plants.

GENERAL CONSIDERATIONS

It is of prime importance in the design of a piping system to provide for the maximum ultimate requirements. This is especially true in trunk lines for water supply mains and drain and waste lines. Experience has shown that as a project develops and expands, more and more demand is placed on these systems. A liberal estimate of ultimate requirements is the best insurance against insufficient capacity in the future.

Next in importance to functionalism in a piping system is that the design shall be economical. This factor involves the proper selection of the material, type, and size of the various pipes, valves, and equipment. It is compounded from a great many elements, some of the more important of which are (1) expected life versus cost, (2) higher pumping costs because of reduced sizes versus smaller initial investment, and (3) increased operating conveniences and reduced maintenance expense versus the added cost for obtaining these features. If these three points are carefully evaluated in the design of each system, it is fairly certain that an economical design will result.

From past experience and from technical data on the subject, the expected life of a pipe or valve may be closely estimated. Obviously, the longer life is more desirable, but it is necessary for the designer to balance the extra years of service against the added cost to obtain it.

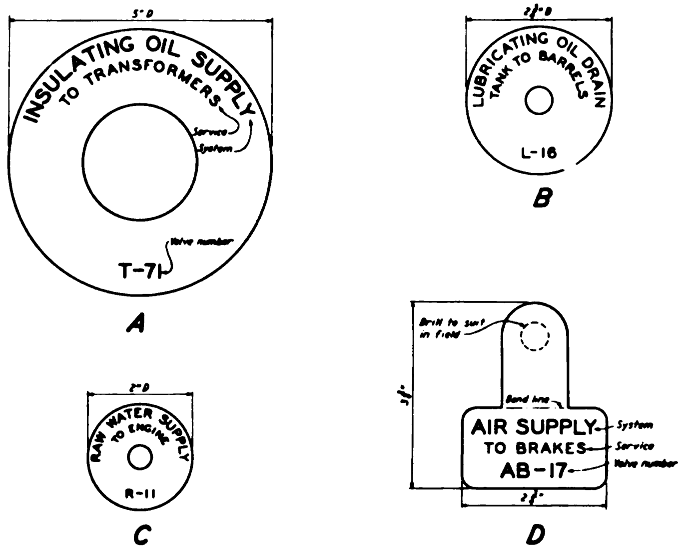


FIGURE 314.—*Valve marker tags.*

The size of each pipeline, once the total flow is established, is almost entirely a function of the pressure drop due to friction in the line. Sizes of equipment connections should never be construed as indicative of proper pipe size. It is necessary to investigate each line for head loss. In evaluating pumping costs and pipe sizes, it must be remembered that station power is cheap in a hydro plant. On the other hand, most of the added cost of a larger size pipe is the material itself, since the labor of installing each line is practically the same. In some cases the size of pipe mains for water systems is dictated by the flow necessary for fire protection. It is advisable not to have too many different sizes and kinds of pipe in a plant since this requires a larger stock of replacement parts for valves and specialties.

The amount of money that should be spent for operating conveniences and reduced maintenance is largely determined by experience and judgment. A good many operating conveniences may be had without extra cost if the systems are properly designed.

METHOD OF FABRICATION AND ERECTION

The most economical way to order material should be carefully considered before any detailed drawings are made, that is, whether pipe assemblies are to be shop fabricated or made up by the field erection forces. The method of handling determines the amount of information to be shown on the detailed drawings as well as that required on the piping bills of material. This decision also influences to some extent the sources from which the materials must be purchased. Some general statements can be made which affect such a decision: (1) It is generally cheaper to shop fabricate com-

plicated piping, pipe of large diameters, and any one type of assembly that occurs in considerable quantity; (2) complicated welded assemblies such as bends, manifolds, and large flanged assemblies should be shop fabricated; (3) the size of the project and the amount of piping required, and who will erect the piping also influences the decision.

The amount of field fabrication work which may be done depends largely upon the size and location of the project and the equipment and personnel available. A well equipped group of pipefitters and welders among the construction force can do much of the fabrication. The design engineer must discuss and coordinate this matter with the project manager and the construction engineer at the start of the project and before any detail drawings are begun.

At the hydro plants the majority of the piping has been largely field fabricated and erected by TVA construction forces. Some of the larger complicated piping assemblies have been purchased as shop fabrications along with pressure vessels and other steel fabrications.

LOCATION OF PIPELINES

During the preliminary stages of the design of a powerhouse, adequate consideration should be given to the physical location of the pipelines. It is absolutely essential that all the various systems be considered as a group in order to lay out the space requirements properly. An illustration of coordinated grouping of piping is illustrated in plate 50 which shows the general arrangement of all piping services connecting to the generators, turbines, and governors at the Boone project. This type of drawing is prepared in the earlier stages of design and is useful to all of the design branches in establishing the plant layout as well as the equipment manufacturers. Close coordination between the pipe designer and the architect and the concrete designer is essential at this stage of the design in order to ensure proper space for pipe galleries, tunnels, and riser shafts. Figure 313 shows a gallery containing a number of piping systems. It will be noted that the gallery is of ample size, that all the pipes are racked along the wall parallel to the building lines, and that they provide adequate headroom.

The use of welding fittings where possible and the uniform spacing of headers result in a piping design which places the accent on simplicity and good appearance as well as functionalism. Valves should be located so that their purpose is apparent at a glance; and they should be accessible, especially those required in an emergency, using chain wheels or motor operators where necessary. There should be sufficient unions in screwed lines to facilitate disassembly. All waste and drain lines, especially those buried in concrete, should have cleanouts at strategic points. The practice of burying plumbing or other piping in walls should be avoided. It is much better to

provide access corridors behind banks of plumbing fixtures for service and maintenance.

DETAILED DRAWINGS AND BILLS OF MATERIAL

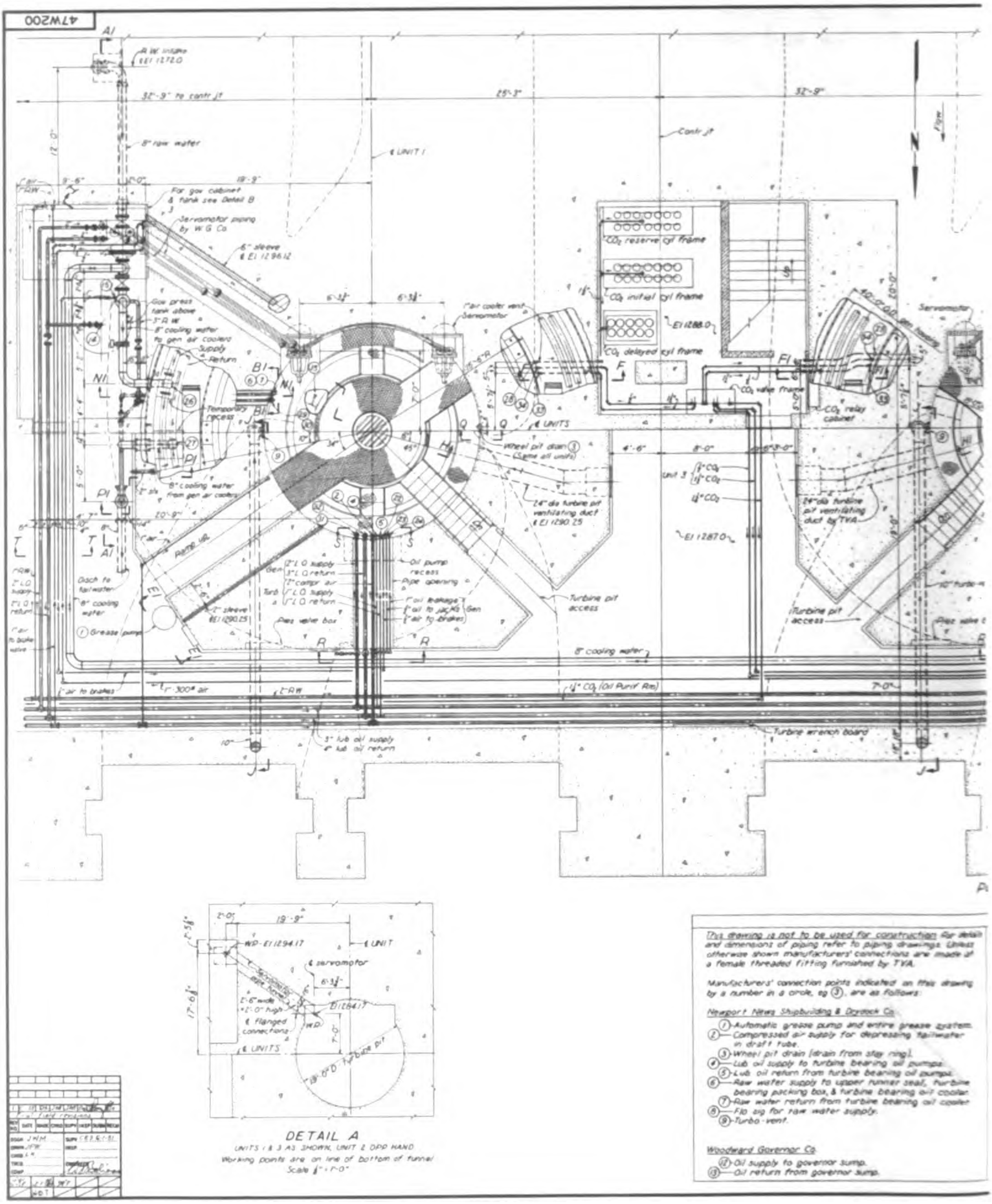
TVA has found it advantageous to make single-line detailed construction drawings for piping systems using pipe 2 inches and smaller and for large-scale yard piping of all sizes. The drawings can be made much faster and, except in some congested areas, they give a satisfactory physical picture. Any congested areas are developed either with standard double-line drawings or by isometric projection. Duplications of views, notations, dimensions, and mark numbers are avoided as they add to the design expense and increase the chances for error. Typical illustrations of single- and double-line detailed drawings are shown in figures 315 and 316.

Standards have been prepared covering the representation of all types of valves, fittings, and piping for both single- and double-line piping drawings (fig. 317). The diameter of each run of piping is always shown on the detailed drawings. In general, the dimensioned centerlines of all piping are shown, but in some instances the location of small piping and its supports can best be determined in the field. The direction of flow is also noted by arrows for each pipeline.

Mark numbers are shown on the drawings for each individual piece of material, except where the greater portion of the material is all of one type or size. These mark numbers are usually shown in circles on the drawings and are prefixed on the separate bills of material with the drawing number. This prevents the possibility of confusion in the field of materials shown on different drawings. Bolts, gaskets, and caulking materials are not marked on the drawing unless of a special design or type. They are, however, always listed on the bill of material.

A bill of material is prepared for each drawing or group of companion drawings. A partial bill of material is shown in figure 318. All materials required by the work shown on the drawings are listed, with the exception of materials which are stocked in bulk in the field, such as tape, solder, flux, sand cloth, thread-cutting lubricants and compounds, paint, cinch anchors, and anchor bolts. The description of each item is as brief as possible but is sufficient to identify the kind and size of material. Standardized descriptions conforming to accepted trade practices have been developed for all types of valves, pipe, fittings, and accessories.

The mark numbers on bills of material are in numerical order, with similar materials grouped together and numbered in blocks to allow for possible future additions as may be required by drawing revisions. Item numbers bearing no relation to the mark numbers are assigned by the procurement engineer who prepares a requisition covering the materials. The item numbers permit sequence of numbering and grouping of like materials when several bills of material are combined for ordering on one requisition.


47W200
DETAIL A
UNITS 1 & 3 AS SHOWN, UNIT 2 OPP HAND
Working points are on line of bottom of tunnel
This drawing is not to be used for construction. For details and dimensions of piping refer to piping drawings. Unless otherwise shown manufacturers' connections are made of a female threaded fitting furnished by TVA.
Manufacturers' connection points indicated on this drawing by a number in a circle, eg 3, are as follows:
Newport News Shipbuilding & Drydock Co.
1 Automatic grease pump and entire grease system.
2 Compressed air supply for depressing tailwater in draft tube.
3 Wheel pit drain (drain from stay ring).
4 Lub oil supply to turbine bearing oil pumps.
5 Lub oil return from turbine bearing oil pumps.
6 Raw water supply to upper runner seal, turbine bearing packing box, & turbine bearing oil cooler.
7 Raw water return from turbine bearing oil cooler.
8 Flo sig for raw water supply.
9 Turbo-vent.
Woodward Governor Co.
12 Oil supply to governor sump.
13 Oil return from governor sump.

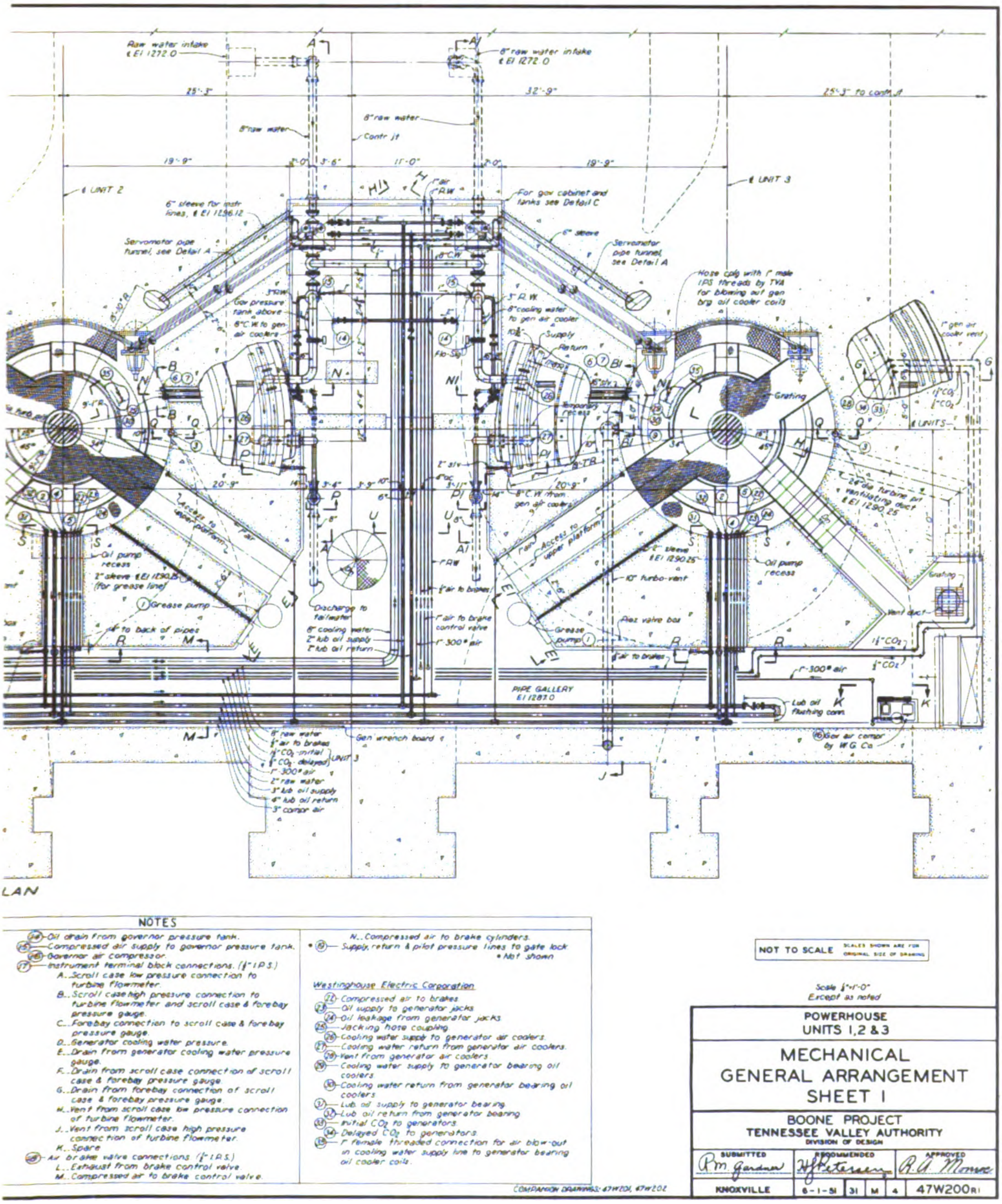

Raw water intake ℄ El 1272.0
8" raw water intake ℄ El 1272.0
8" raw water
Contr jt
℄ UNIT 2
℄ UNIT 3
6" sleeve for instr lines, ℄ El 1296.12
Servomotor pipe tunnel, see Detail A
For gov cabinet and tanks see Detail C
6" sleeve
Hose cplg with 1" male IPS threads by TVA for blowing out gen brg oil cooler coils
Gov pressure tank above
8" C W to gen air coolers
8" cooling water to gen air cooler
Supply
Return
Grating
Temporary recess
1" gen air cooler vent
24" dia turbine air ventilating duct ℄ El 1290.25
Access to upper platform
Oil pump recess
2" sleeve ℄ El 1290.5 (for grease line)
Grease pump
4" to back of pipes
Discharge to tailwater
8" cooling water
2" lub oil supply
2" lub oil return
1" air to brake control valve
1" 300# air
1" air to brakes
10" turbo-vent
Air valve box
PIPE GALLERY El 1287.0
1" 300# air
Lub oil flushing conn
Gov air compr by W G Co
Gen wrench board
8" raw water
1" air to brakes
1" CO₂ - initial
1" CO₂ - delayed
UNIT 3
1" 300# air
2" raw water
3" lub oil supply
4" lub oil return
3" compr air
PLAN
NOTES
(14) Oil drain from governor pressure tank.
(15) Compressed air supply to governor pressure tank.
(16) Governor air compressor.
(17) Instrument terminal block connections. (½" I.P.S.)
A..Scroll case low pressure connection to turbine flowmeter.
B..Scroll case high pressure connection to turbine flowmeter and scroll case & forebay pressure gauge.
C..Forebay connection to scroll case & forebay pressure gauge.
D..Generator cooling water pressure.
E..Drain from generator cooling water pressure gauge.
F..Drain from scroll case connection of scroll case & forebay pressure gauge.
G..Drain from forebay connection of scroll case & forebay pressure gauge.
H..Vent from scroll case low pressure connection of turbine flowmeter.
J..Vent from scroll case high pressure connection of turbine flowmeter.
K..Spare
(18) Air brake valve connections (½" I.P.S.)
L..Exhaust from brake control valve.
M..Compressed air to brake control valve.
N..Compressed air to brake cylinders.
• (19) Supply, return & pilot pressure lines to gate lock
• Not shown
Westinghouse Electric Corporation
(22) Compressed air to brakes.
(23) Oil supply to generator jacks.
(24) Oil leakage from generator jacks.
(25) Jacking hose coupling.
(26) Cooling water supply to generator air coolers.
(27) Cooling water return from generator air coolers.
(28) Vent from generator air coolers.
(29) Cooling water supply to generator bearing oil coolers.
(30) Cooling water return from generator bearing oil coolers.
(31) Lub. oil supply to generator bearing.
(32) Lub oil return from generator bearing.
(33) Initial CO₂ to generators.
(34) Delayed CO₂ to generators.
(35) 1" female threaded connection for air blow-out in cooling water supply line to generator bearing oil cooler coils.
COMPANION DRAWINGS: 47W201, 47W202
NOT TO SCALE
SCALES SHOWN ARE FOR ORIGINAL SIZE OF DRAWING
Scale ⅛"=1'-0"
Except as noted
POWERHOUSE
UNITS 1,2 & 3
MECHANICAL
GENERAL ARRANGEMENT
SHEET 1
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
6-1-51
31
M
4
47W200R1

PLATE 50

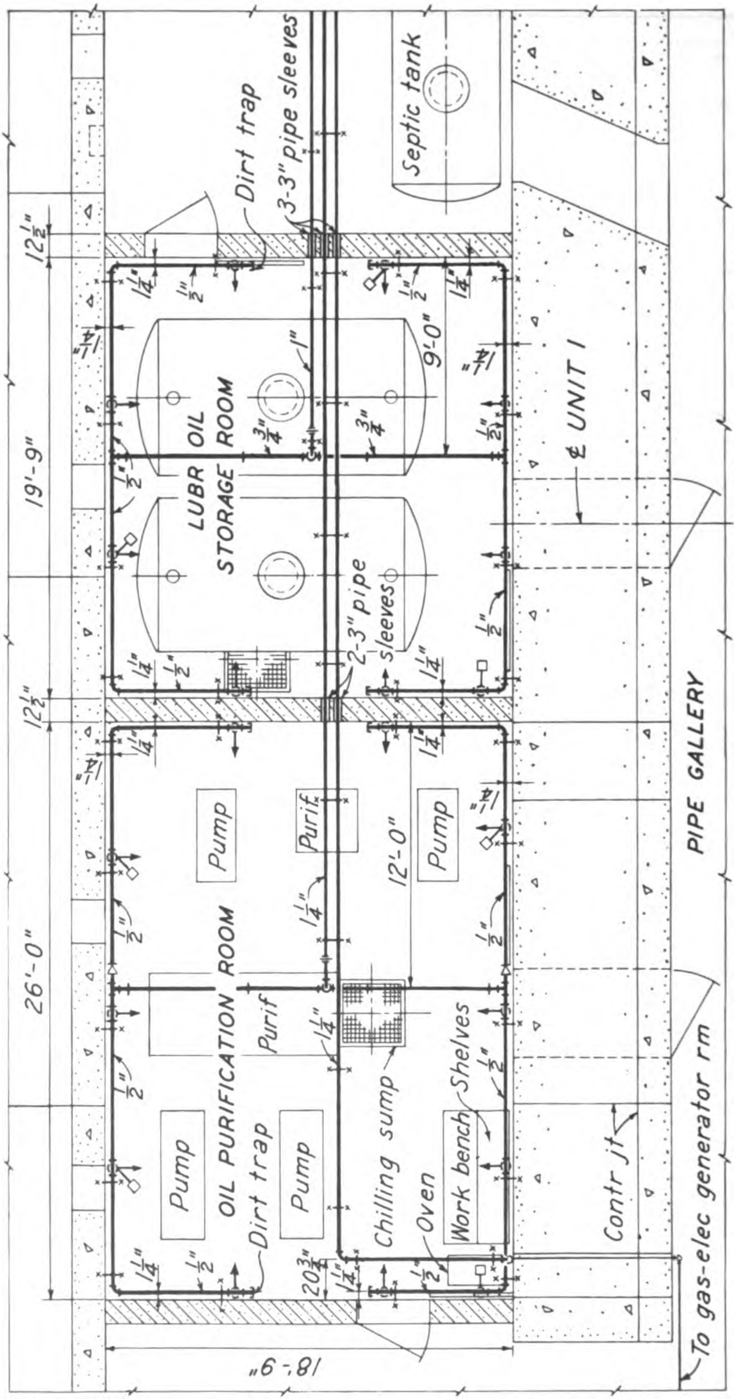


FIGURE 315.—*Typical single line piping detail drawing.*

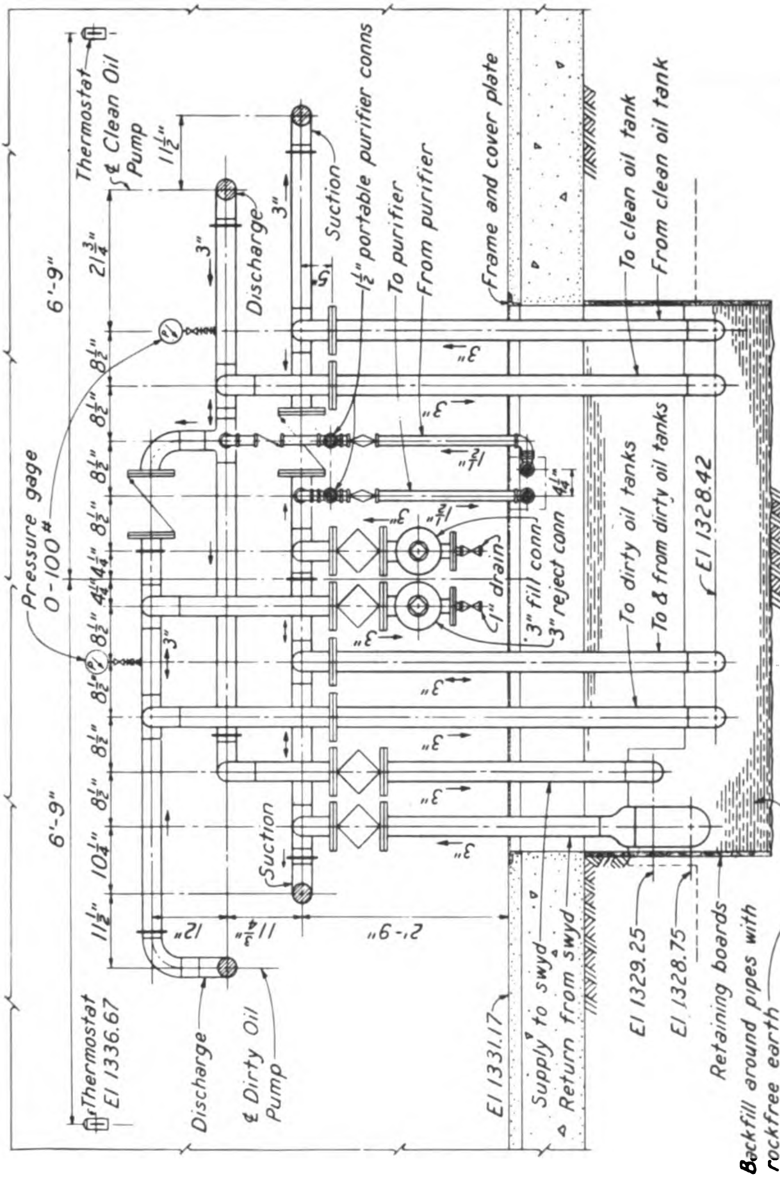


FIGURE 316.—*Typical double line piping detail drawing.*

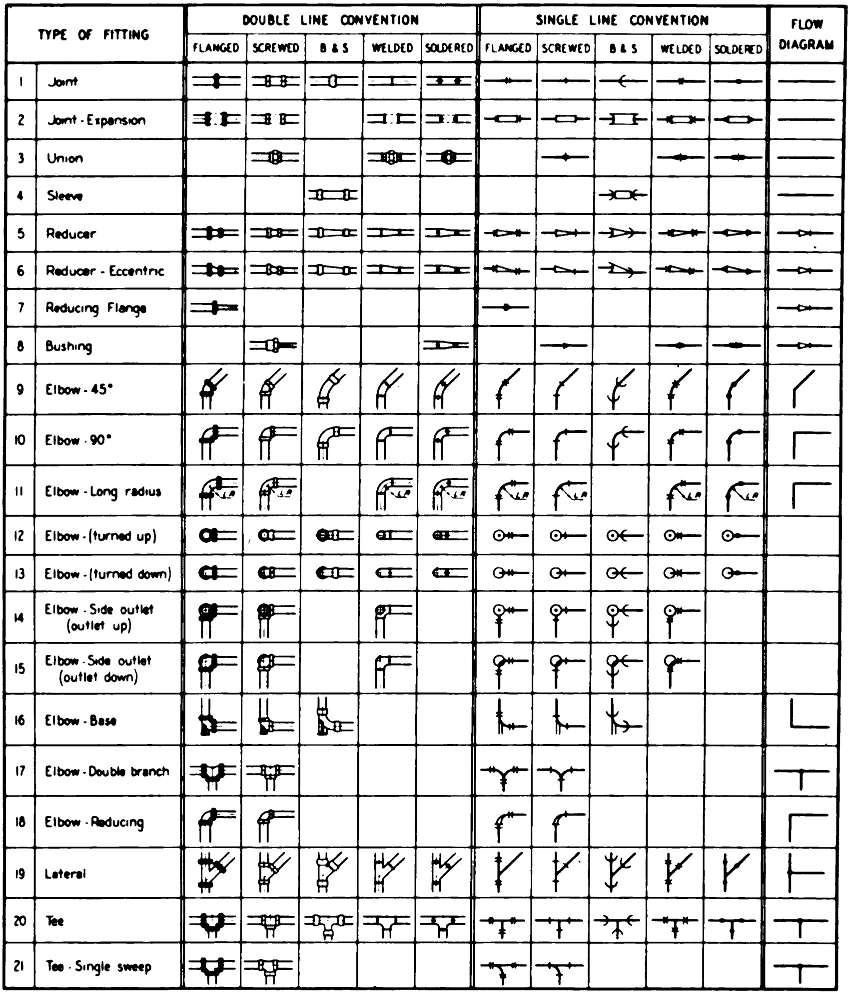
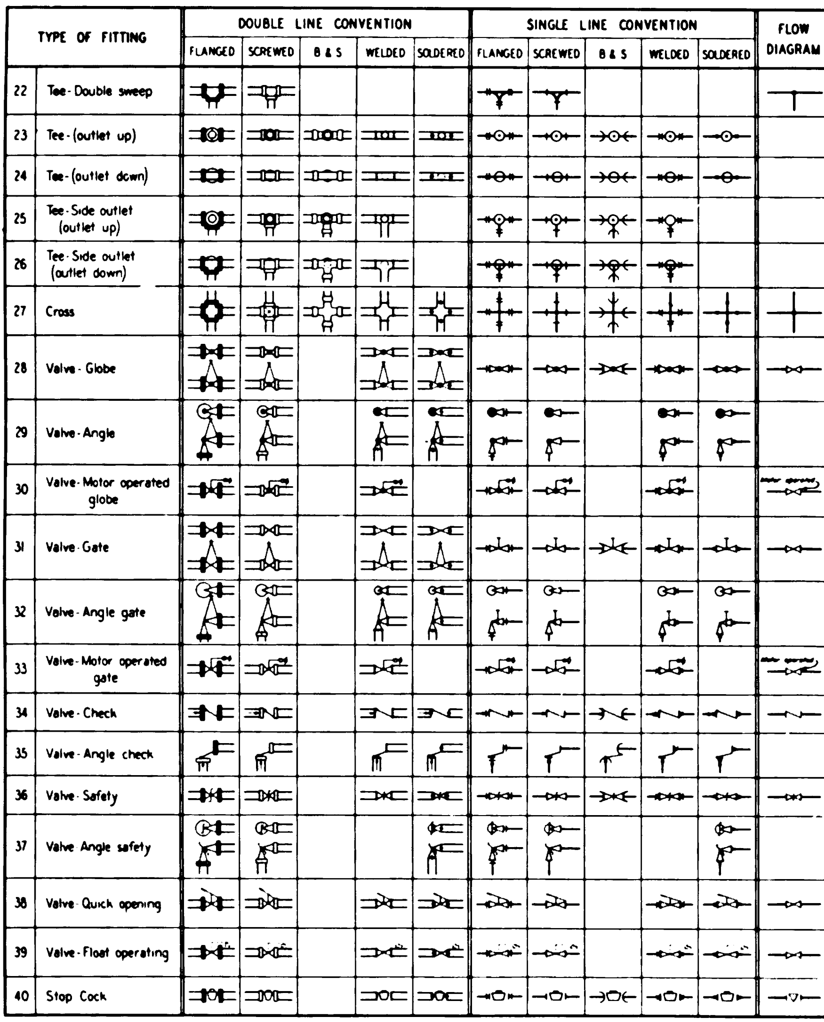


Figure 317.—*Symbols for*



pipe fittings and valves.

Classification letters are assigned to all materials listed on bill of material to make possible the allocation of cost to the various services covered. The classification system is for the use of the job accountant who is responsible for determining the final cost of each individual service in accordance with Federal Power Commission procedures. The established TVA code of classification letters shown on bill of material is as follows:

Classification letter	Service
A	Lubricating oil
B	Insulating oil
C_1	Raw water—cooling generators
C_2	Raw water—fire protection
C_3	Raw water—service, flushing, sprinkling
D	Treated water—service
D_1	Treated water—fire protection
E	CO_2 fire-extinguishing system
F	Compressed air
G	Drains
H	Instruments and piezometer lines
J	Plumbing
K	Gasoline
L	Grease lubrication
M	Gas-electric generator exhaust
N	Vent lines (other than plumbing)
O	Gage well lines
P	Grout piping
X	Rotor jacking oil
Y	Runner hub oil
AC	Air conditioning

PIPING MATERIALS

Preceding chapters covering the design of the individual piping systems have described in general the types of piping materials utilized. Piping material standards were developed by TVA for the use and guidance of the designer. These standards are continually subject to change as new types of material become available, and for this reason they are not presented herein. Furthermore, during World War II it was necessary due to governmental restrictions concerning the use of vital materials to utilize certain substitute materials. Since the war a great many improved types of piping material have become available. Although TVA prefers to employ only proven types of piping materials it also takes advantage of the latest developed materials.

Pipe

The type of pipe is largely determined by the class, service, and size utilized for a particular piping system. The greatest part of the steel pipe used by TVA is purchased under ASTM Specification A 120, standard weight (ASA–B36.10, Schedule 40). For certain pipe assemblies, where considerable bending or coiling of the pipe is necessary, the pipe is specified as ASTM A 53, Grade A. Wrought-iron pipe is purchased under ASTM Specification A 72. All cast-iron pipe is bell and spigot plain end or mechanical joint, centrifugally cast, with class depending on the pressure. Cast-iron pipe for pressure lines is purchased cement-lined, as it may generally be had at no increase in price, and experience has proved that it is

TVA 7070 (DES 6-46)

TENNESSEE VALLEY AUTHORITY - DIVISION OF DESIGN

ITEM NO	ARTICLES OR SERVICES	QUANTITY	UNIT	MARK NO	REFERENCE NO	CLASSIFICATION
				47N2606	HM-	
	Bushings - Steel, hexagon, black, threaded right hand.					
219	1-1/4" x 3/4"	1	only	275	329	F
220	1-1/4" x 1/4"	1	only	276		F
221	3/4" x 1/4"	2	each	277		F
222	1/2" x 3/8"	1	only	278		X
	Bushings - Iron, hexagon, threaded right hand.					
	(Black)					
206	3" x 1"	1	only	285		F
211	2" x 1"	2	each	286		F
212	2" x 3/4"	1	only	287		C1
214	1" x 1/2"	1	only	288		F
	(Galvanized)					
218	2" x 1"	1	only	295		D
	Half couplings - Extra heavy, steel, threaded right hand, black.					
168	1"	1	only	300	329	F
169	3/4"	2	each	301		C1
172	1/2"	4	each	302		2C1,2F
173	1/4"	3	each	303		1C1,2F
	Welding outlets - Drop-forged steel, black, Bonney Forge and Tool Works "WELDOLETS," or equal.					
273	10" x 3"	1	only	310		C1

MADE RCP	CHKD JM	SUP CES	HYDR CWB	APP RMO

REVISIONS	NO.	DATE	MADE	CHKD	APP.	DESCRIPTION

PIPING BILL OF MATERIAL

HIWASSEE UNIT 2 PROJECT

AIR, OIL, AND WATER LINES

DWG NOS 47N2606, 2607, 2608

KNOXVILLE, TENN DATE 12-28-54

SH 11 OF 19 5 W 447BM2606

FIGURE 318.—*Typical piping bill of material.*

much more resistant to tuberculation and has a better coefficient of friction. Cast-iron pipe is purchased in 16- to 18-foot lengths, depending on the supplier. Because of the added caulking expense, 12-foot lengths are seldom used. In some of the larger size mains (14 inches and above), it has proved advantageous to use spiral-welded pipe. This is especially true in drainage lines embedded in concrete where the cost of steel or cast-iron pipe would be excessive. Vitrified clay or concrete pipe is used for underground sanitary sewers and some building drain lines.

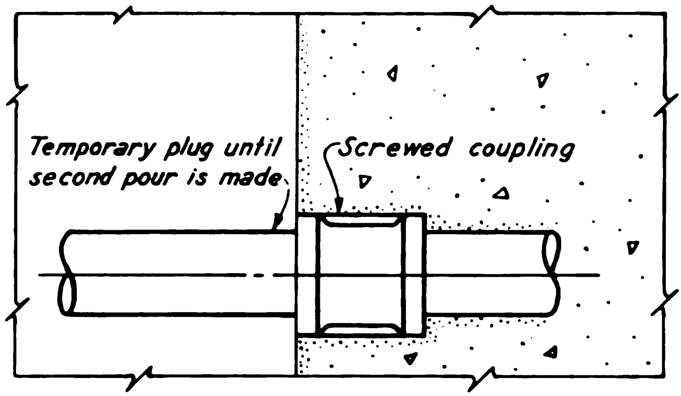


FIGURE 319.—*Typical screwed coupling for small pipeline emerging from concrete.*

Steel pipe is purchased in random lengths with ends threaded and coupled, or beveled for welding, as the case may be. It is cheaper to weld pipes 4 inches and larger than to use screwed flanges and threaded fittings. It also saves time and expense to have complicated welding pipe assemblies shop-welded into subassemblies which are then welded together in the field.

Where lines lead directly to headwater or tailwater, heavier construction is used up to the first valve in the system to guard against possible breakage which, if it occurred, would possibly flood portions of the powerhouse and repair would be extremely difficult. A special connection is used where embedded lines leave the concrete in the various galleries. In smaller lines a screwed coupling is placed flush with the face of the concrete wall; this permits ready replacement in case of breakage in the line. In larger lines a standard cast-iron sleeve is placed flush with the concrete wall, and the exposed pipe (steel or cast iron) is caulked therein. Cast-iron lines emerging from concrete are placed with the end of a bell flush with the wall. These two types of connections are shown in figures 319 and 320.

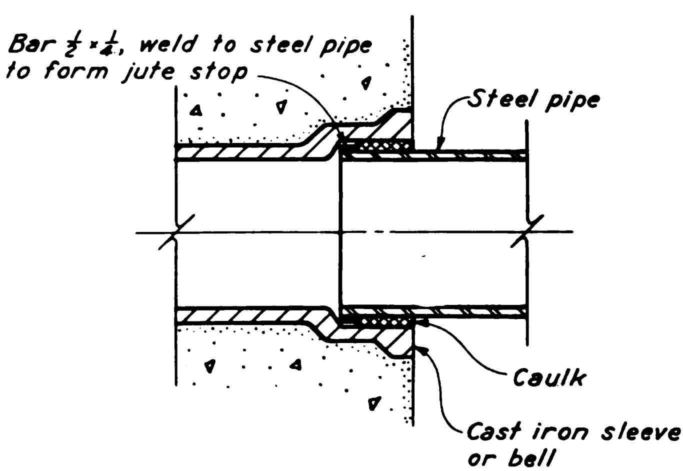


FIGURE 320.—*Typical cast iron bell coupling for large pipeline emerging from concrete.*

Pipes passing through walls and floors are sleeved, with sleeves in floors extending 1 inch above the floor to permit floor washing without water spilling to the room below. Piping systems are provided with drains at the low points to facilitate repairs and to drain waterlines which are subject to freezing. A good pipe designer always provides a closure piece in a pipe system between two pieces of equipment where there are intervening flanged fittings or valves instead of designing the system fitting to fitting. This is necessary because fittings and valves never are furnished to exact dimensions and the closure piece takes up the inaccuracies in dimensions. Pipelines are arranged to provide adequate access to machinery for inspection and repair and to permit the removal of equipment without the necessity of dismantling large sections of piping.

Fittings

Fittings generally conform to the American Standards Association Specifications. Fittings usually are selected to match the adjoining pipe and are galvanized when the pipe is galvanized, except that cast-iron fittings are generally purchased with a black finish and are only galvanized in exceptional cases. Screwed fittings, depending upon the service and pressure, are provided in standard cast iron, cast-iron drainage, malleable iron, forged steel, and brass. Recessed cast-iron drainage systems are used almost exclusively in plumbing waste and drain lines to avoid stoppage. Flanged fittings are furnished faced and drilled in cast iron or steel in appropriate pressure ratings. Welding fittings of the butt-welding type are purchased in both wrought iron and steel to match the wall thickness of adjoining pipe. Steel welding fittings conform to ASTM Specification A 234, with cast or mitered fittings being excluded. Forged steel socket-welding type fittings are used in the small size welded lines. Cast-iron bell and spigot and mechanical joint fittings are to AWWA Specifications. Solder-joint cast-bronze or drawn fittings are provided for copper tubing used mainly in the plumbing systems, piezometer, and instrument lines.

Faced and drilled cast-iron flanges are used in screwed piping systems and forged steel welding flanges of both the slip-on and welding-neck type are provided for welded piping systems. When steel and cast-iron flanges are mated, the raised face on the steel flange leaves a $\frac{1}{16}$-inch gap between the flanges. Care should be exercised in drawing up the bolts in a joint of this kind or the cast-iron flange may crack. A good practice is to machine-off the raised face on the steel flange, thus making full contact on the face of each flange.

Vitrified clay or concrete fittings are used to match similar type pipe installed in underground sewer and building drainage systems.

Screwed unions with brass seating ring and ground joint are generally used in smaller size pipelines with flanged, gasket-type unions being used in $2\frac{1}{2}$-inch size and larger. Ground joint forged steel and cast-bronze solder joint unions are utilized for certain services.

Welding or backing rings are utilized in all welded piping systems at each pipe joint where the pipe size is 3 inches in diameter and larger. These rings assist the piping erector in centering and

joining two sections of pipe preparatory to a welding operation. They also prevent welding icicles from forming inside the pipeline and make the job of cleaning the completed piping system much easier.

Compressed air and water service connections for 1-inch hose attachment are provided throughout the powerhouse. These service connections in the gallery areas are usually exposed along the wall; in areas where appearance is of importance, they are installed in recessed wall cabinets. A typical service cabinet and hose coupling are shown in figure 321. Globe and angle valves are utilized for this purpose. The hose couplings are of rough red brass and are of the universal type to match end connections on the air and water hose.

Globe and gate valves

The function of a valve in a piping system is either to regulate the flow of the fluid in the line or to sectionalize a piece of equip-

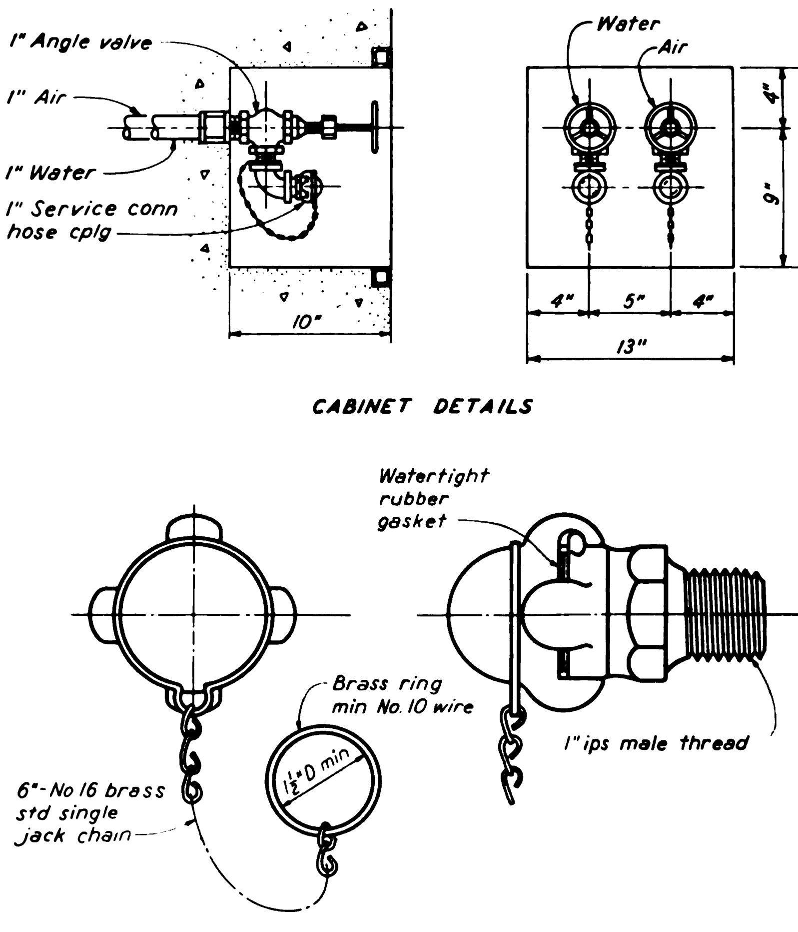


FIGURE 321.—*Typical compressed air and water service outlets.*

ment or part of the system. Globe valves are used for the first function and gate valves for the second.

Because of its internal construction, a globe valve is better suited for partly open position during flow; hence its desirability for flow control. It is also easier to repair and is, therefore, more suitable for the greater wear occasioned by throttling. A gate valve used for throttling will chatter and wiredraw, and flow across the seal will damage it. However, a globe valve directs the flow through two 90° turns, adding considerably to the pressure drop, whereas a wide open gate valve offers only slightly more resistance to the flow than an equivalent length of pipe. Since most of the valves in hydro plants require only infrequent operation and are seldom used for throttling service, gate valves are used in the majority of cases. Globe valves are used on bypasses around special valves and regulators with a gate valve on either side of the equipment bypassed.

TVA prefers a rising stem valve to a nonrising stem valve because the position of the stem indicates the position of the disk and because the stem threads are not in contact with the fluid. The outside screw and yoke type of rising stem valve has the further advantage that the stem threads are outside the valve when open, making it possible to examine and lubricate them, if necessary, with the valve in service. The additional headroom required for the rising stem valve over a nonrising stem valve is of small importance, except in special cases.

Globe valves are usually purchased with plug-type disk because that type of disk gives excellent throttling service, has greater resistance to wear, and is easily repaired. The so-called composition disk has not proved satisfactory for throttling and wears out quickly. Gate valves 2 inches and larger are usually purchased with double disks and smaller than 2 inches with wedge disks. A double-disk valve gives a tighter shutoff. Sometimes a larger size wedge disk valve is used when it is impossible to install the valve with the stem up. In this position the disk of the double-disk valve is liable to jam. Gate valves smaller than 2 inches are purchased with wedge disks because, in our opinion, the various parts in a double-disk valve in those sizes are too small.

Valves 2 inches and smaller, both gate and globe, are usually purchased all brass or bronze. Larger valves are purchased iron or steel body, depending upon pressure requirements and are bronze-mounted. The use of cleanouts in valve bodies has not been found necessary nor has it been necessary to specify air-tested valves except for those used in CO_2 systems which operate at 850-pound-per-square-inch pressure. Pressures encountered in hydroelectric plants seldom call for bypasses around valves, although at times it has been necessary to provide gearing for the larger size valves (14 inches and up). This, of course, is a function of the pressure on the valve and is investigated for each condition. Larger valves which require fast operation, or are remotely controlled, are fitted with motor operators.

Check valves

Check valves are used on the discharge of pumps and at all other places where it is imperative to prevent backflow of the fluid. Swing

check valves are preferred, but in some cases lift check valves are used, especially for upward flow. A balanced disk or spring-loaded check valve is used to prevent slamming and excessive surges in the higher head lines.

Control valves

Control valves are used by TVA in hydro plants for pressure regulating, temperature regulating, pressure relief, maintaining liquid level, and actuating flow to automatic water fire-protection systems.

Pressure regulating valves are used for reducing the water pressure to generator air and oil coolers, turbine oil coolers and runner seals, air-conditioning equipment, air compressor jackets and after-coolers, and general plant services. Where the pressure drop is low, direct-operated spring-loaded diaphragm valves are installed, while for high-pressure drop, pilot-operated valves are used. The pilot-operated valves are of the hydraulic or pneumatic type. The pneumatic type has proved more satisfactory for use on raw river water, as trouble has been experienced with the hydraulic type due to fouling of the pilot valves, necessitating the installation of strainers in the pilot lines. Filters should be installed in the air lines of pneumatically controlled valves. Small valves and valves used for dead end service are single-seated, while large valves are generally double-seated or balanced construction. A pressure gage is always installed on either side of a reducing station.

The sizing of pressure regulating valves for hydro plants presents a problem because of varying headwater elevations. Since the valves must pass the required amount of water under any load condition, a valve large enough under low headwater may be too large under maximum headwater levels. Likewise a regulating valve on plant service sometimes must also be designed for fire protection. This means that water requirements must be estimated very closely, and valves must be selected so that they have characteristics best suited for their particular service.

Both spring-loaded hydraulic relief valves and diaphragm back-pressure valves have been used after pressure regulating valves. Spring-loaded hydraulic relief valves have proved satisfactory in small sizes and where close control is required. Relief valves are sized to pass the total amount of water which the pressure regulating valve will pass under highest head conditions.

Two types of temperature regulating valves are used, i.e., solenoid-operated and motor-operated from a thermostatic element. Solenoid valves are used on air compressor jackets and similar services to control cooling water to prevent flow and condensation when the service is intermittent. Direct thermostatic valves are used on cooling water for air-conditioning equipment. Motor-operated valves, actuated from thermostatic elements, are used on air-conditioning equipment and to control the cooling water to generator air coolers in remotely controlled plants.

Level controls are used in conjunction with flow control valves for maintaining levels in open tanks and for actuating the air admission valves to draft tube tailwater depressing systems for unit motoring. Ordinary balanced float or altitude valves are used to maintain a constant level in an open tank from a pressure main.

Float-operated mercury switches are utilized to actuate remotely controlled valves.

Several types of valves have been used for open and shut service to control the flow of water to fire-protection sprinkler systems. These have included manual lever-operated quick-opening gates, motor-operated gates, solenoid-operated, spring-controlled globes, solenoid-operated diaphragm-controlled air-operated and water-operated globes, and solenoid-controlled, hydraulically operated piston type check valves. The latter type has proven the most satisfactory in several respects. A typical valves installation of this type is shown in figure 280, page 576, of chapter 13, "Fire Protection."

Caulking materials and thread lubricants

Cast-iron bell and spigot or plain end pressure pipe joints for raw water and drainage service are usually made by caulking three rings of dry braided jute in the bell, leaving a cavity 2½ inches deep, and filling the remainder of the bell with molten lead in one continuous pour and caulking. Similar joints in treated or domestic waterlines are made in the same manner except that three rings of commercially available, sterilized paper packing is utilized instead of jute. Virgin pig lead is specified, with no reclaimed lead being used.

Cast-iron soil pipe joints are made in a similar manner to cast-iron pressure pipe joints except only one ring of dry twisted jute is used.

Vitrified clay and concrete sewer and drain line pipe joints have bells and spigots treated with a primer and joined together by caulking a 1-inch ring of dry twisted jute into the bell and filling the remaining portion of the bell with a hot asphalt compound.

Sulphur compounds of various types have been used instead of lead for making cast-iron pipe joints. The sulphur compound weighs much less than lead, has a lower melting point, and requires no caulking which tends to reduce the labor cost. Sulphur compound joints, however, will leak to some extent until the joint is completely set and for this reason it may be necessary to delay trench backfilling operations for several days until all leakage disappears or is corrected. Lead-caulked joints appear to be more resistant to leakage and pipeline breaks caused by vibration, shock, and settlement apparently due to the plasticity of the lead. Good bell and spigot joints can be made of cement if the proper mixture is utilized and the technique is well known.

Joints in mechanical joint cast-iron pipe and fittings are made up in accordance with ASA Specification A21.11. The ease and savings in labor costs involved in installing mechanical joint cast-iron pipe as compared to making up bell and spigot pipe joints has tended to favor the purchase of mechanical joint pipe in several instances.

Graphite and linseed oil are used as thread lubricants for pipelines carrying CO_2, raw and treated water, drainage, and ordinary waste lines and oil resistant compound or Glyptol as a thread lubricant on compressed air and oil lines.

Wrapping tapes

The problem of corrosion of underground piping is more serious at TVA steam plants due to the leeching out of the sulphur in the coal pile. At the hydro plants, however, underground piping is also subject to corrosion due to the adverse effects of varying types of earth and backfill and to some extent is subject to deterioration caused by electrolytic action.

Various types of polyvinyl and polyethylene plastic tapes have been used for wrapping underground steel and wrough-iron pipelines. Plastic tape is furnished in varying widths depending upon the pipe diameter and is wrapped spirally on the pipe by hand or with a wrapping machine, using a half lap of the tape. Such tape should be applied with no more stretch than would be imparted to it by unwrapping it freely from a rotating roll. Tape having a thickness of 0.020 inch is used for wrapping straight runs of pipe and fittings are double-wrapped with 0.010-inch-thick tape. Wrapping machines may be purchased or rented from plastic tape manufacturers and suppliers.

Closely woven fabric tape, coated on both sides and saturated with coal tar has also been used successfully for wrapping underground pipelines for corrosion control (fig. 322). This tape which is commercially available is usually purchased in 50-foot rolls, in varying widths, depending upon the pipe diameter. The tape is applied with the use of a torch to bleed the coal tar coating for a perfect bond. Wrapping is done spirally and overlapping slightly

FIGURE 322.—*Pipe for underground service*

being wrapped with coal-tar saturated tape.

more than half the width of the tape. Tape 2 inches wide is used on $1\frac{1}{2}$-inch-diameter and smaller pipe, 3-inch-wide tape on 2- through 3-inch diameter, and 4-inch width on larger diameters. Fittings are double-wrapped with 2-inch-wide tape. The finished thickness of this type of wrapping tape is in the order of 0.10 inch and would seem to afford considerably more protection to the pipe than the thinner plastic tapes and greater resistance to being cut or pierced by sharp stones which may be present in the backfill.

Both types of wrapping tape, in addition to providing a moisture-proof barrier against corrosion, also have high dielectric strength properties which should protect the pipe against electrolysis.

Bolts and gaskets

Flange bolts usually conform to ASTM Specification A 107, American Standard steel machine bolts, coarse-thread series (ASA B1.1), class 2 fit, having regular unfinished square heads and heavy semifinished hexagon nuts. Bolt studs are purchased according to ASTM Specification A 108 as commercial steel, threaded full length with two semifinished hexagon nuts conforming to ASTM A 107. Stud bolts are purchased under the same specification as bolt studs. The designer should be careful in specifying bolt studs and stud bolts as these are two different types of bolts. A bolt stud is threaded to the standard diameter either on both ends or the full length with a nut assembled on each end and is customarily used for bolting two flanges together. The stud bolt is threaded on both ends, one end being threaded to the standard diameter for a nut assembly and the other end specially threaded to match threads of tapped holes. The stud bolt is usually employed for joining a pipe flange to a piece of equipment which has tapped holes.

Where bolts are used underwater and are subject to excessive corrosion, or are not readily accessible—such as anchor bolts embedded in concrete for fastening water inlet and drainage gratings—stainless steel bolts and nuts are usually employed.

Anchor bolts for large equipment are usually of steel and are cast into the concrete in pipe sleeves to permit adjustment. Cinch anchor bolts are utilized for smaller equipment and the attachment of pipe hangers, anchors, and supports. Slotted, strip type inserts are sometimes cast in concrete ceilings and walls where support for groups or banks of pipe is required.

Flanged gaskets are usually purchased in $\frac{1}{16}$-inch thickness or as thin as possible consistent with the roughness of the flange. Fiber gaskets, treated to resist oil are utilized for compressed air service, insulating, lubricating, and runner hub oil. Red rubber gaskets are provided for most cold water and drainage services. Ring type gaskets are used in preference to full face gaskets as they make a tighter joint. Where full face gaskets are necessary they are purchased with the bolt holes punched for the appropriate flange drilling. Gaskets for compressed air and oil lines are painted with compound, allowed to dry, and again painted with compound immediately before bolting the flanges.

Pipeline expansion

In all pipelines subject to temperature changes, stresses and forces occasioned by expansion, unless relieved, are of great magnitude. If free movement of the pipeline is restricted, not only are the pipe wall and joints subject to high stresses but severe thrusts are also exerted against anchors and equipment. While the temperatures encountered in hydro plant piping systems are not as high as those found in the steam plants, the lengths of pipelines in a multiunit hydro plant do call for some expansion design. A very large part of piping troubles may be laid to neglect of providing for expansion.

Several methods are employed to permit free pipeline movement caused by temperature changes:

1. Slip-type expansion joints.
2. Packless expansion joints (corrugated metal and rubber).
3. Expansion pipe bends.
4. Change in direction in pipeline.

Where space permits, expansion pipe bends or change in direction of the pipeline is preferred. By deflection they permit the free expansion of the piping with only a small additional pressure drop due to the added length through which the fluid must travel. The deflection or movement of the bend depends upon several factors; the radius, diameter of pipe, moment of inertia of the pipe, length and rigidity of the adjoining straight pipe sections, and the effect of flattening of the pipe section during flexure. Mathematical formulas and tables have been developed which include these variables.

The slip-type expansion joint consists of a plunger to which the pipe is connected, and it is designed to move longitudinally in the barrel of a housing which is usually securely anchored. Leakage past the plunger is prevented by a packed stuffing box. This type of joint is expensive both in first cost and installation but can be justified if a considerable amount of expansion is needed and space is not available for conventional pipe bends. The stuffing box feature, however, must be carefully maintained to ensure against pipeline leakage.

Corrugated metal, packless-type joints permit pipeline expansion by means of the bellows action of the corrugations or flexible members. The corrugated section is usually held between two flanges or welding ends in the larger sizes but may be furnished with screwed ends for small pipelines. Copper is used for lower temperatures and pressures and stainless steel or other alloys for higher temperatures and pressures or where a particular corrosion problem exists. This type of joint can be installed in a limited space and requires very little attention.

Rubber expansion joints employ a reinforced rubber bellows with flanged connections. They find many useful applications on pipelines where pressure and temperatures are low and the fluid is not injurious to rubber. These are also available for vacuum service. This joint is particularly useful on pipelines near pumps or other equipment to reduce the transmission of vibration into the rest of the piping system or the building structure. Due to the joint's flexibility and axial deflection, slight misalignment of pipeline

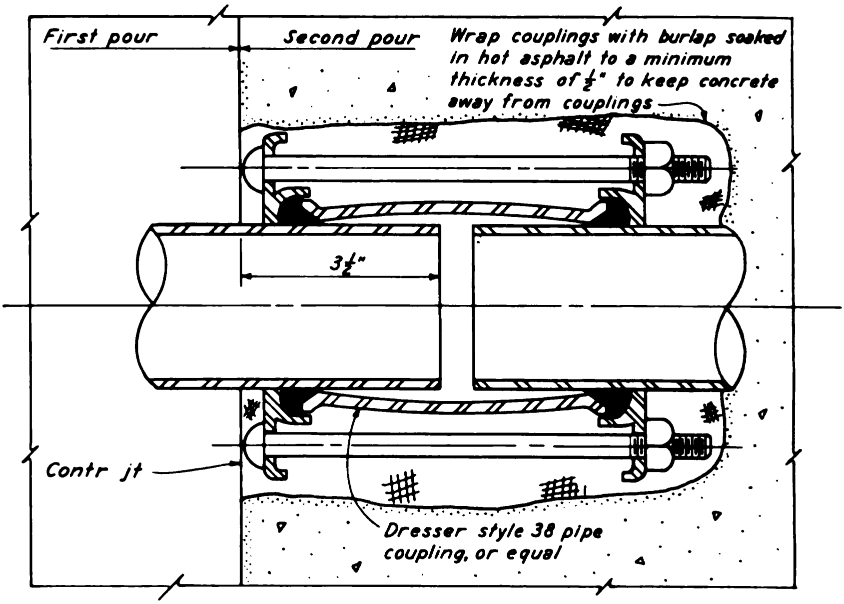


FIGURE 323.—*Typical rubber-gasketed contraction joint crossing.*

joints may also be absorbed, thus reducing expensive remachining and rewelding of several pipeline connections.

Along with the matter of expansion of pipelines, the problem of proper anchoring and guiding must be carefully considered. Anchors must be so placed to ensure pipe movement in the direction planned.

Provision for expansion is also made in all pipelines embedded in concrete where contraction joints are crossed. For pressure lines a rubber-gasketed, slip-type coupling is sometimes installed in the second concrete block to be poured against the first poured block from which the plain end of the pipe extends. Figure 323 illustrates a typical joint crossing of this type. The slip-type joint is wrapped with asphalt-saturated burlap to protect the coupling bolts and to provide for some extent for vertical deflection caused by unequal settlement between the adjacent concrete blocks.

On large diameter pressure lines and some gravity pressure drain and unwatering lines a cast-iron sleeve is embedded flush with the concrete in the first block poured and the connecting pipe from the adjacent block is leaded and caulked into the sleeve (fig. 324). Some space is left between the two pipe ends in the sleeve to accommodate contraction and expansion occurring between the adjacent concrete blocks. This type of joint crossing will not accommodate a great amount of unequal vertical settlement between the concrete blocks.

Where considerable vertical settlement between concrete blocks may be anticipated on embedded gravity pressure drain lines, the pipe is cut flush with the concrete at the contraction joint and a double flexible sheet-metal seal is embedded in the concrete, around the pipe, and across the contraction joint.

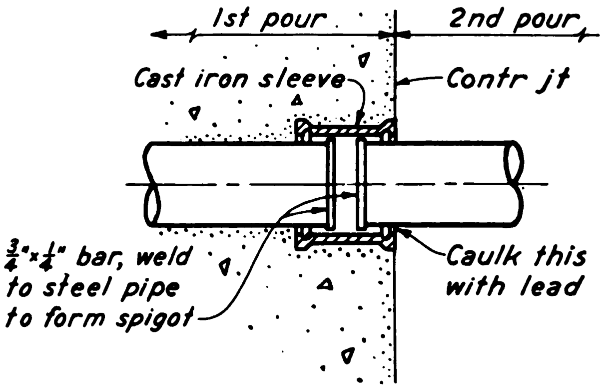


FIGURE 324.—*Typical caulked contraction joint crossing.*

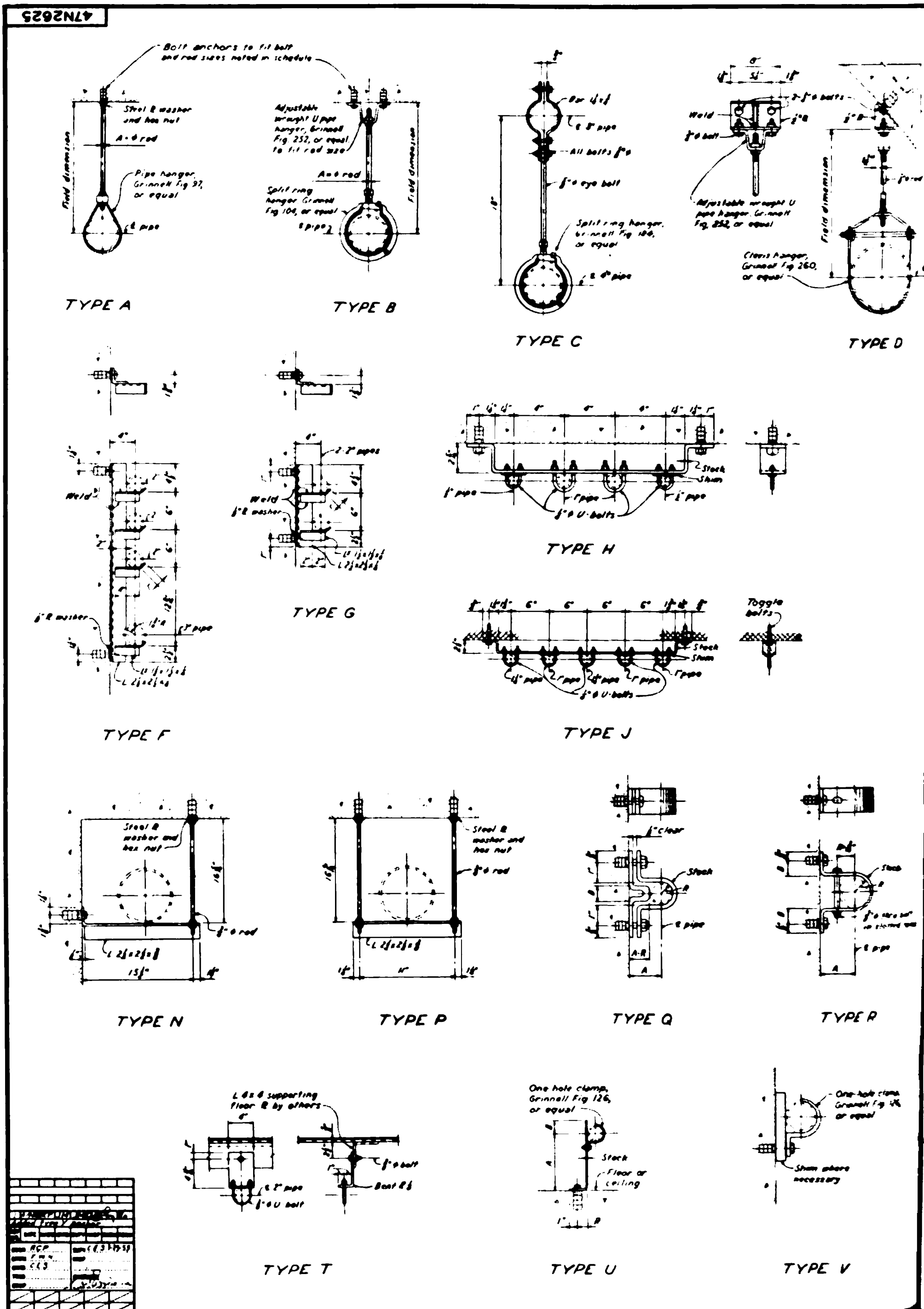
Hangers and supports

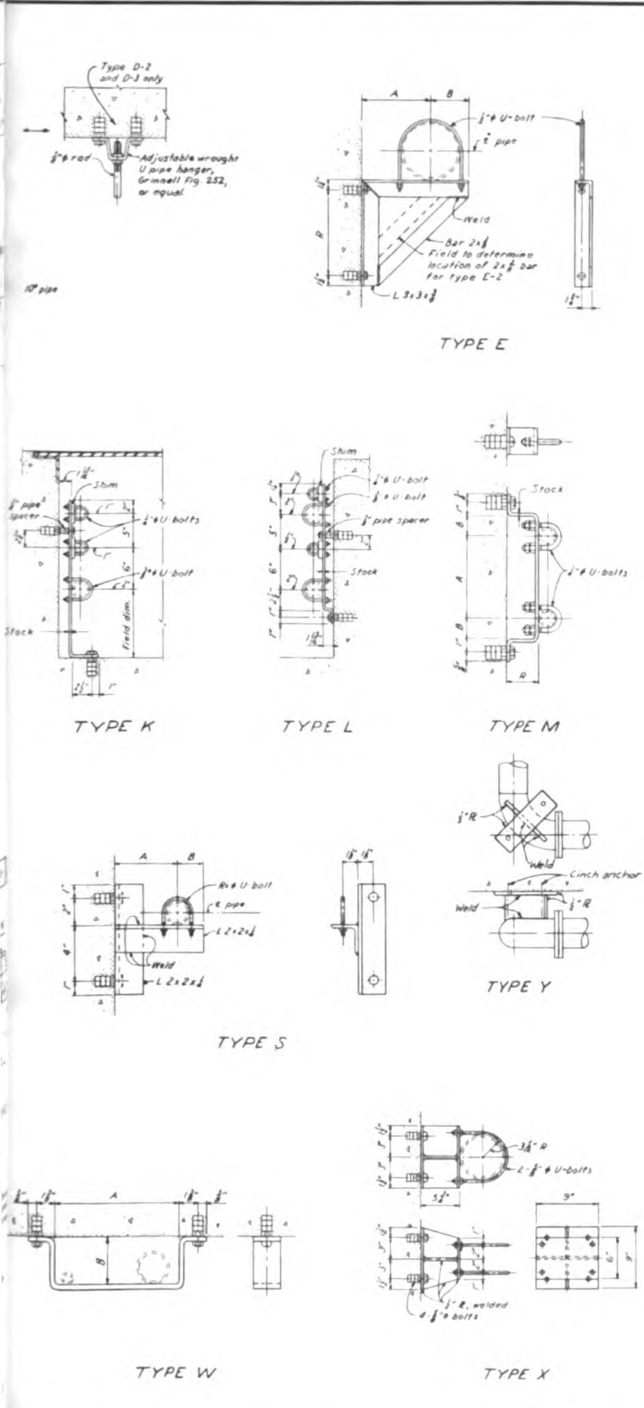
In a well-designed piping system, the piping should always be supported so that stresses transmitted to any of the valves or machinery are reduced to a minimum. The stresses introduced in equipment in this manner, coupled with vibration, may eventually break the casting of a pump or valve. The possibility of transmitting vibration into the building structure should also be examined.

For economical erection and satisfactory operation, the details of supports and hangers, in general, should be the problem of the designer and not left to the judgment of the erection forces, who may not be fully acquainted with the weights and forces encountered.

Standard commercial hangers are used where possible as they are generally cheaper than designing special types. Pipe hanger manufacturers provide many types of hangers, supports, and anchors with all necessary accessories from which the designer can select materials which will take care of the majority of his supporting problems. These manufacturers also publish technical data concerning the weight-carrying characteristics of their products. All types of hangers and supports should permit vertical adjustment. Each support should be sufficient to carry its proportionate share of the load, which includes the weight of the pipeline and insulation and the weight of the pipeline fluid. A factor of safety should be used in any calculations, as an expanding pipeline may lift clear of one or more hangers and concentrate the entire weight of that section upon adjacent supports. With preengineered spring or constant support hangers this factor of safety may be considerably reduced, as these types compensate for any pipe movement, if properly adjusted.

TVA prepares detailed pipe hanger and support drawings which show and label by types the majority of the supports required. Plate 51 shows a typical pipe hanger drawing, which includes hangers made up of standard commercially manufactured items as well as special supporting brackets or anchors which may be fabricated by the erection forces from structural shapes and plates. In designing pipe supports the designer should always bear in mind


47N2625
TYPE A
TYPE B
TYPE C
TYPE D
TYPE F
TYPE G
TYPE H
TYPE J
TYPE N
TYPE P
TYPE Q
TYPE R
TYPE T
TYPE U
TYPE V



SCHEDULE

LOCATED ON DWG NO.	TYPE & MK NO.	NO. REQD	SIZE OF PIPE	DIMENSIONS A	B	R	BOLT DIA.	STOCK	REMARKS
47N2606 47N2607 47N2608	A-1	1	3"	1/2"					
	B-1	2	8"	3/8"			3/4"		
	C-1	1	3" & 4"						
	D-1	2	10"						On sloping ceiling
	D-2	2	10"				3/4"		On level ceiling
	D-3	1	10"				3/4"		On valve yoke
	E-1	5	8"	10"	5 1/2"	12 1/2"	3/4"		
	E-2	1	6"	16"	4 1/2"	17 1/2"	3/4"		
	F-1	4					3/4"		
	G-1	1					3/4"		
	H-1	1					1/2"	2"x1/2"	
	K-1	2					1/2"	2"x1/4"	
	L-1	2					1/2"	2"x1/2"	
	N-1	6	8"				3/4"		
	P-1	4	8"						
	Q-1	1	2"	3"	2 1/8"	1 1/16"	3/4"	2"x1/4"	
	Q-3	2	1 1/4"	4"	1 1/2"	7/8"	3/4"	2"x1/4"	
	Q-4	1	2"	2 1/2"	2 1/8"	1 1/16"	3/4"	2"x1/4"	
	Q-8	1	3/4"	3"	3/4"	1/2"	1/2"	1 1/4"x3/16"	
	Q-9	3	1/2"	2"	3/4"	1/2"	1/2"	1 1/4"x3/16"	
	Q-10	1	3/8"	3"	9/16"	3/8"	1/2"	1 1/4"x3/16"	
	R-2	3	1 1/4"	3"	1 1/4"	1/2"	3/4"	2"x1/4"	
	R-3	3	1"	3"	1 1/4"	11/16"	3/4"	2"x1/4"	
	R-5	3	3/4"	4"	1"	9/16"	1/2"	1 1/4"x3/16"	
	R-6	5	1/2"	3"	1"	1/2"	1/2"	1 1/4"x3/16"	No thru bolt
	S-2	1	1"	6"	1 1/4"	1/4"	5/8"		
	T-1	2	2"				3/4"	4"x5/16"	
	V-1	2	1"				1/2"		
	V-2	7	3/4"				1/2"		
	V-3	24	1/2"				1/2"		
	W-1	7	—	9"	3 1/4"		3/4"	2"x3/4"	
	X-1	1	—						
47N2611	A-1	1	3"	1/2"					
	A-2	2	1"	5/8"					
	B-2	8	6"	3/4"			5/8"		
	J-1	1					1/2"	2x1/4"	Use toggle bolts
	Q-2	1	1 1/2"	3"	1 1/2"	15/16"	5/8"	2"x1/4"	
	Q-6	1	1/2"	3"	1/2"	5/16"	1/2"	1 1/4"x3/16"	
	Q-7	2	1/2"	2 1/2"	3/8"	5/16"	1/2"	1 1/4"x3/16"	Use toggle bolts
	R-1	1	1 1/2"	2"	1 1/4"	13/16"	3/4"	2"x1/4"	No thru bolt
	R-2	1	1 1/4"	3"	1 1/4"	5/8"	3/4"	2"x1/4"	
	R-3	6	1"	3"	1 1/4"	11/16"	3/4"	2"x1/4"	
	R-4	1	1"	3"	1 1/4"	11/16"	3/4"	2"x1/4"	No thru bolt
	S-1	6	1 1/2"	4 1/2"	2"	5/8"	1/2"		
	U-1	1	1 1/2"	9"	1"	1 1/4"	3/4"	2"x1/4"	
	U-3	6	1/2"	2"	1/2"	1"	1/2"	1"x3/16"	
	U-4	4	1/2"	2"	1/2"	1"	1/2"	1"x3/16"	Use 3/8" clamp
	V-4	2	1/2"				5/16"		Use 3/8" clamp
47N2622	M-2	1	2"-1/2"	3"	1 1/4"	1 1/2"	1/2"	1 1/4"x3/16"	
	U-2	2	1/2"	6"	1/2"	5"	1/2"	1 1/4"x3/16"	
	V-2	4	1/2"				1/2"		
	V-3	6	1/2"				1/2"		
47N2802 47N2803	M-1	1	2-1"	6"	1 1/2"	2 1/16"	3/4"	2"x1/4"	
	Q-5	1	1"	6"	1 1/8"	11/16"	3/4"	2"x1/4"	
	R-3	1	1"	3"	1 1/4"	11/16"	3/4"	2"x1/4"	
	S-2	1	1"	6"	1 1/4"	1/4"	5/8"		
	V-4	4	1/2"				5/16"		Use 3/8" clamp
47N2606	Y-1	2	8"				3/4"		

NOTES:
1. Field to cut insulation to clear hangers where necessary.
2. All material to be furnished and fabricated by Field.
3. Bar stock, bolts, angles, etc. may be increased in size to suit field stock.
4. Typical indication for bolt anchor.
5. Hangers and guides = } Symbols used on location drawings.
Anchors =

Not to scale

POWERHOUSE

MECHANICAL
ANCHORS & HANGERS

HIWASSEE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
R.M. Gardner	W.J. Petersen	R.A. Monroe

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that hanger details must allow for ready erection and possible future dismantling of the pipeline. In most cases, the type and location of hangers, supports, and anchors are determined and indicated on the detailed piping drawings before actual field installation is begun except for such lines as may have to be located by the erection forces. This assists the erector in that he does not have to provide temporary pipeline supports.

If concrete inserts are to be used to support piping it is important that their location be determined as early as possible for placement in the concrete. Strip-type inserts should be used for large diameter and multiple banks of piping to accommodate misalignment.

Single pipeline hangers for small lines may be best supported by use of cinch anchor bolts set at the time the piping is erected. Other design branches concerned with the structural details of floors and walls should be advised of the location and loading which must be carried by pipe supports and anchors.

Elbows and tees in bell and spigot cast-iron pipelines should be anchored against internal pressure surges or pipeline movements which may tend to loosen the caulked joints and create leakage. In such pipelines emerging from concrete, steel straps are utilized to secure the pipe into the caulked joint. In underground piping, concrete anchor blocks are cast around the elbows and tees and are bedded against the trench walls prior to backfilling. An illustration of this type of anchor is shown in figure 325.

Insulation

Many types of insulating materials have been used by TVA for the insulation of pipelines. During this period many excellent new types of materials have been developed by the manufacturers and the older types have been improved or superseded. In general, the problem of insulating pipelines in hydro plants is relatively simple as compared to the high temperature heat insulating problems involved in a modern steam plant. In a hydro plant the majority of the pipe insulation required is for the prevention of the formation of condensation on the exterior of cold raw and treated waterlines and connecting equipment and drain lines. Such insulation is not for the purpose of retarding heat absorption by the water but is to prevent sweating of the pipelines where such would be objectionable from the standpoint of housekeeping or damage to adjacent equipment and the building structure. It serves the further important function from the maintenance standpoint of preventing the rusting and replacement of the pipe and lessens the painting expense which might otherwise be involved.

Some pipe insulation is required for hot waterlines in the plumbing systems for conservation of heat and a minor amount is required for low temperature use in the air-conditioning refrigeration and chilled water systems as well as on long runs of cooled waterlines serving drinking fountains. In some cases insulation to prevent freezing is required on exposed outdoor waterlines. The subject of insulation for ductwork, generator housings for semi-outdoor plants, hatch covers, and refrigeration equipment is discussed in chapter 14, covering heating, ventilating, and air conditioning.

After the detailed piping drawings are completed, sets of white prints are prepared, on which the various pipelines and equipment to be insulated are colored in crayon with each color representing a different kind of insulation. From these drawings a bill of material of the required insulating materials is made and a requisition is issued covering their purchase. Sets of the colored drawings together with a construction specification covering the application of the insulating materials are issued to the TVA construction forces in the field. A typical construction specification for this type of work is included in appendix D.

Until recent years TVA's own construction forces handled the installation of most of the hydro plant pipe insulation. However, it has recently been found advantageous to contract this type of work in hydro plants in spite of the small volume, largely due to the preference of the asbestos worker to work for a contractor. When work of this nature is contracted the design branch prepares the same type of colored sets of drawings which, accompanied by specifications, are sent out with the invitations to bid. It has been found that colored sets of drawings used for this purpose specifically define the various types of insulation for the different piping services and clearly show the extent of the work. Lump sum prices are usually obtained for both the labor and the material portion of the work and a single contract is usually made to cover both phases. Such invitations to bid generally include breakdown unit prices for both materials and labor which are convenient for price adjustment in case the scope of the work is altered after award of the initial contract.

The general types of insulation specified for hydro plant piping systems and the corresponding colors used on the marked detailed drawings to represent the various types are as follows:

Color symbol	Piping system	Type of insulation		Finish
		Pipe	Fittings	
Red	Cold raw and treated water, drainage and waste (inside building).	Wool felt or antisweat	Asbestos cement over built-up wool felt.	Canvas jacket.
Blue	Cold water pump casings, strainers, and large related piping and valves (inside building).	Regranulated cork and primer or corkmastic.	Same as pipe	None.
Orange	Cold water (in exposed outdoor locations).	Layer of hairfelt between inside and outside layer of wool felt.	do	Coated weatherproof jacket.
Brown	Chilled water (inside building).	Fiberglass or cork	Rockwool or felted mineral wool.	Sealing compound and glass paint.
Green	Hot water (inside building).	85% magnesia or asbestos corrugated paper.	Asbestos cement	Canvas jacket.
Yellow	Gasoline engine exhaust lines (inside building).	Combination high temperature insulation and 85% magnesia moulded.	do	Asbestos cloth jacket.

The thickness of insulation is determined in each case by the size of the pipe and the temperature of the pipeline fluid or gas. Insulation 1 inch thick has been found to be sufficient to prevent sweating on waterlines for the river water temperatures and air

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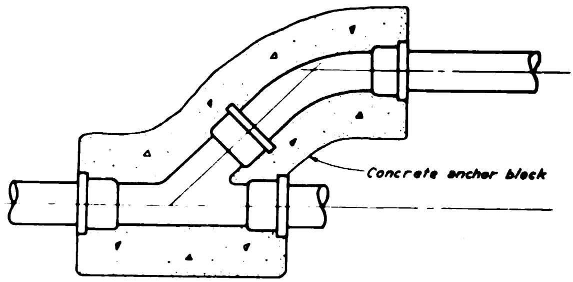

FIGURE 325.—*Typical concrete anchor block for cast iron underground waterlines.*

humidities encountered in most of the low head hydro plants, and $1\frac{1}{2}$-inch-thick insulation is generally needed in the high head tributary plants due to the colder river water temperatures which sometimes range as low as 36° F. It has also been found that $\frac{3}{8}$-inch-thick regranulated cork or corkmastic used on cold water pump casings, water strainers, and large valves and manifolds is satisfactory for medium water temperatures but is not suitable for colder river water temperatures. In the latter case such equipment is usually covered with $1\frac{1}{2}$-inch-thick hairfelt or woolfelt and finished with either asbestos cement or a canvas jacket. Figure 326 shows a typical group of cold waterlines covered with anti-sweat insulation and figure 327 shows regranulated cork insulation on a strainer and large valves and piping.

Pipe, valves, fittings, and equipment are pressure-tested, cleaned of all scale, rust, grease, dirt, and other foreign matter and the outer surface made dry before any insulation is applied. Throughout the insulating procedure it is imperative that no water be admitted to the inside of the pipelines or equipment being covered to avoid condensation on the exterior surface. There have been cases

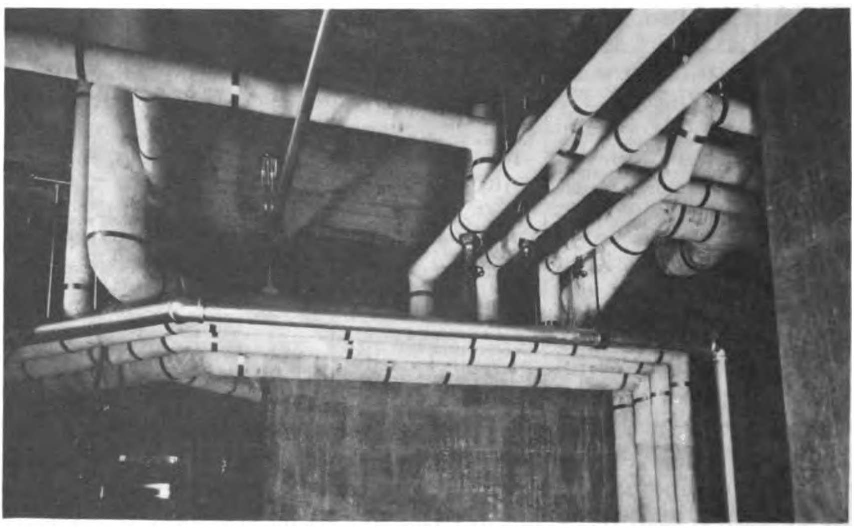

FIGURE 326.—*Antisweat insulation for cold water pipelines before painting—Pickwick Landing.*

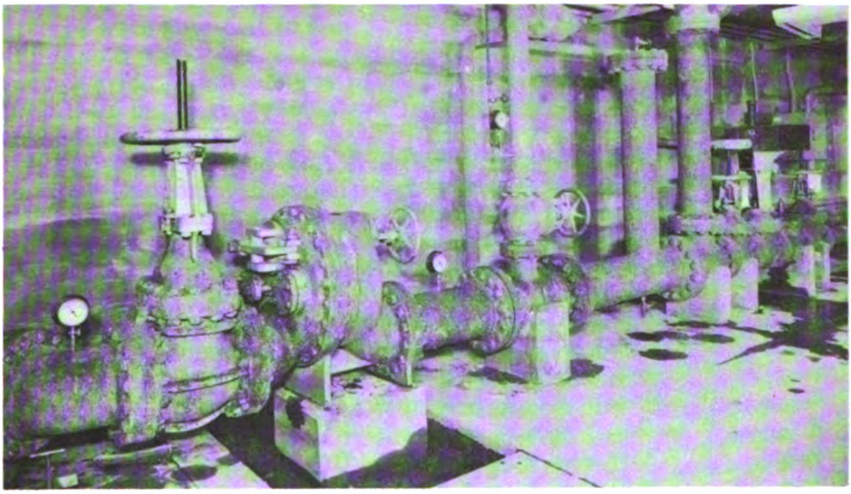

Figure 327.—*Regranulated cork insulation on large valves, strainers, and piping—Ocoee No. 3.*

where this procedure was not followed and the regranulated cork insulation would not set dry and had to be removed and replaced. In other instances condensation on the pipeline rotted the insulation.

Pipeline flanges are generally insulated unless otherwise specified. Valves are insulated up to the bonnet only. Whenever possible, insulation for straight piping is furnished in moulded form in 3-foot lengths in double-layer construction. The outer layer is applied so as to stagger the joints in the inner layer, and longitudinal laps are sealed. Careful sealing of all joints is essential to prevent the entrance of moisture and vapor into the insulation. Moulded insulation is generally furnished with a shop-pasted canvas jacket and metal bonds to hold the insulation in place. Where roll canvas or asbestos cloth is required it is applied with an approved type adhesive rather than sewing. Pasting of jackets has been found to be much more economical and quite satisfactory. The adhesive also acts as a sizing agent for the canvas or asbestos cloth and materially speeds up the finish painting process.

Cutouts are made in the insulation for pipe covering protection saddles where used in connection with pipe supports and anchors, and the saddles are packed with hairfelt. On some types of insulated lines No. 18 gage sheet-metal saddles extending half way around the pipe are placed over the insulation at the hanger supports for insulation protection. For typical types of saddle supports and shields used in conjunction with pipe insulation, see figure 328.

Cleaning, testing, and sterilizing

During the laying and jointing of water pipelines every practical precaution is taken to keep the interior of the pipe, fittings, and other accessories free from dirt and foreign matter. At times when installation work is not in progress the open ends of pipe are closed before the work is stopped. Joints which cannot be finished during a given working period should be temporarily caulked with packing

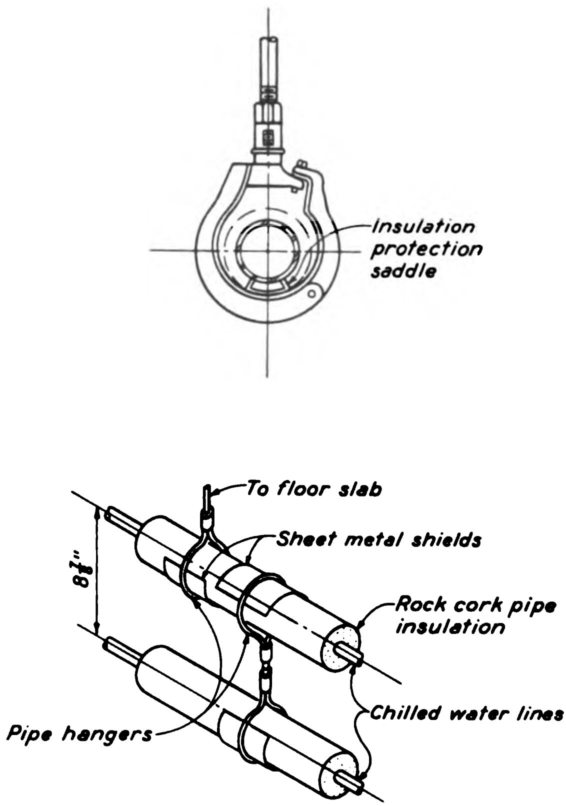

FIGURE 328.—*Typical insulation saddle supports and shields.*

to make them substantially watertight. This is particularly true of domestic water systems where sterilization is ultimately required but also applies to most of the other piping systems. A wide variety of materials such as bottles, sacks, wooden plugs, axe handles, and other foreign objects have frequently been found in completed piping systems and have been known to seriously retard the flow and in some cases cause damage to pump impellers and other equipment. Waterlines are generally flushed out by continuous pumping over a considerable period of time. These lines are hydrostatically pressure-tested at a pressure of at least 150 percent of the maximum expected working pressure. The cleaning and testing of buried waterlines is done before trenches are backfilled. Similarly, all plumbing lines encased in concrete, tile walls, or partitions are cleaned and tested prior to erection of the walls.

All oil pipelines are cleaned thoroughly so that they are free from scale, rust, welding icicles, and foreign matter and are hammered and wire-brushed to facilitate the cleaning process. After this procedure they are flushed with oil or kerosene and pressure-tested with oil at not less than 150 percent of the maximum expected working pressure. In the earlier design days pipe for oil systems was pur-

chased under a "scale free" specification and valves and certain fittings were specified to be pickled for scale removal. Later designs eliminated this type of specification, largely due to the fact that such service is not always available from the supplier and it was found to be more economical and possible to do a good job by efficient field cleaning.

Compressed air and CO_2 lines are blown out with compressed air to clear the lines of scale, dust, and welding icicles. Compressed air lines are air-tested at 150 percent of the working pressure.

Drainage pipelines are usually blown out with compressed air or flushed with water and are tested by filling with water to the highest point in the system.

A standard specification was developed by TVA to cover the disinfection of domestic water distribution systems, including mains, pipes, standpipes, tanks, and all parts of the system with which water comes in contact. The requirements of this specification were developed by the TVA Divisions of Design, and of Health and Safety to conform with TVA policies and operations, and a section on bacteriological examination and approval is included to assure provision of a safe drinking water. Disinfection is required as a public health safeguard after a potable water distribution system has carried raw or polluted water, after completion of a new system, and after completion of maintenance or repair operations which may contaminate any part of the system.

The preflushing, chlorination, final flushing, testing, and sampling is done under the supervision of the Division of Health and Safety resident sanitary engineer. After preflushing, all parts of the system are filled with disinfecting solution sufficient to produce a minimum chloride residual of 100 parts per million at the time of filling. The minimum chlorine residual permitted at the end of a 24-hour retention period at the points most remote from the point of chlorination is 25 parts per million. The Drop Dilution Test is usually utilized to determine the residual from collected samples from all parts of the system.

Following a satisfactory sterilization the complete system is thoroughly flushed out with approved treated water. After this flushing and the system is filled with approved treated water, two more samples are collected and submitted for bacteriological examination in accordance with instructions furnished by the resident sanitary engineer. After at least two successive bacteriological examinations of samples taken at intervals of not less than 24 hours indicate negative tests for coliform organisms, approval is given for placing the system in service.

Appendix D includes complete Construction Specification G–11 covering the disinfection of water systems.

Painting

All piping systems of TVA, including all insulation, are painted for appearance, protection, and identification, in accordance with a standard color code. Each system has its own color and this stand-

ard, which is shown in the following tabulation, is maintained throughout all the plants.

Piping to be painted aluminum. Flanges of fittings and valves (except drains) and bands to be painted with designating color.

Piping system	*Identifying color*
Compressed air	Orange yellow
CO_2	Tartar red
Filtered water—hot	Light blue
Filtered water—cold	Dark blue
Raw water	Ivory
Lubricating oil supply	Cinnamon brown
Lock high pressure oil supply	Cinnamon brown
Lubricating oil return	Lemon yellow
Lock high pressure oil return	Lemon yellow
Transil oil supply	Medium green
Lock gates control	Medium green
Transil oil return	Light green
Lock filling and emptying control	Light green
Drains	Black

The whole system is first painted with an aluminum paint, and identification is obtained by painting the periphery of flanges or by painting an occasional screwed elbow or tee, as the case may be, with the color of that particular system. If the length of line between these identification points is long, a narrow band is painted around the pipe at intervals. Occasionally pipeline nomenclature is stenciled on large-diameter lines, and arrows are sometimes painted on pipelines where the direction of flow is not evident at a glance.

INSTRUMENTS AND CONTROLS

When compared with a modern steam-electric generating station of comparable capacity the number and type of mechanical instruments required for a hydro plant are both very small. Those which are required, however, must be reliable and used to the best advantage. TVA from its experience over the years has more or less standardized on the type of instruments and the locations where instruments have been found desirable or necessary. A brief description of these instruments and the purpose they serve is given below.

Pressure gages

Practically all pressure gages in TVA hydro plants have been the indicating type, recording gauges having been found unnecessary. They are used on all water and oil pressure lines, compressed air lines, pressure tanks, and governor cabinets. Compound gages are provided on all lines where a vacuum is liable to occur, such as cooling water discharge lines, pump suction lines, gasoline suction lines, and draft tube mandoors. In addition to the use of gages to indicate pressure in a line, they are also provided on either side of water strainers to indicate by differential pressure the condition of the strainer baskets.

Gages are usually 4½-inch dial diameter and of the bronze bourdon tube type with rotary gear movement. They are located di-

rectly on the piping where such installation is feasible. Where gages on the piping would be difficult for the operator to see, they are located on a wall, column, or panelboard and piped to point of connection.

Thermometers

Industrial thermometers on the discharge lines from air compressors indicate to the operators the condition of the valves in the compressor. On the oil purifiers they indicate the temperature of the oil to the centrifuge and an auxiliary equipment jacket cooling waterlines.

Dial thermometers are provided on the governor cabinets by the governor manufacturer to indicate the temperature of generator guide and thrust bearings and in the high head plants are also provided for the turbine guide bearings.

A three-pen recording thermometer on the governor cabinet records the temperature of the cooling water to the unit and the temperature of the water bearing, the generator air coolers, and the generator bearing oil coolers.

Flowmeters and flow indicators

Manometer-type indicating flowmeters operating from a thin metal orifice are provided for the generator air cooling water supply lines. These meters, shown in figure 219, page 450, are calibrated to read in gallons per minute and have adjustable electrical contacts to operate an alarm or annunciator in case of low flow.

Manometer-type indicating and totalizing flowmeters, as shown in figure 329, are also provided for measuring the water flow through the turbine. These meters are located on the governor cabinet and are connected to piezometer taps located in the turbine scroll case.

Flow indicators of the swinging-gate type, shown in figure 220, page 451, are provided in the cooling waterlines to the generator and turbine bearing oil coolers. These instruments have scales graduated from 0 to 10 indicating the proportion of total flow but not gallons per minute. They also have adjustable electrical contacts to operate an alarm or annunciator in case of low flow. In the remote control plants an additional electrical contact in these instruments shuts down the unit in case of very low cooling water flow.

Integrating meters of the positive-displacement or current type have been provided in various plants for metering treated water especially where the water was purchased from an outside source.

Indicating mercury manometers have been provided to indicate the flow to pressure filters and chemical feeders.

Sight-flow indicators are provided on bearing cooling water discharge lines and other locations where a closed discharge line is necessary.

Open funnels are provided on air compressor and after cooler water-lines and all other locations where such devices are feasible, as an open funnel enables the operator not only to see that cooling water is flowing but also to judge the water temperature by feeling.

Level indicators

Where oil or water tanks are located inside the buildings or above ground they are provided with gauge classes to indicate liquid level. Underground tanks have remote-type level indicators.

Level controls

Float switches to start and stop pumps are usually provided on water storage tanks. Two switches are required on such installations, one to start the pump at some predetermined low level and one to stop the pump at high level. These switches generally have mercury contacts and float cages mounted in the piping external to the tanks.

Piezometers

In the main-river plants, piezometer connections are usually provided for the turbine flowmeter (fig. 329) and forebay water pressure. In plants with long penstocks, connections for net head indication have been provided instead of forebay pressure connections. Two connections are also provided on long penstocks for Gibson Test.

Piezometers have also been provided in various plants for special purposes. At Fort Loudoun, piezometers are installed in one overflow section of the dam. At Ocoee No. 3, Apalachia, and Watauga there are piezometers in the surge tank outer shell and riser. In plants having Howell-Bunger valves in the spillway, piezometers meter the water flow in case it should be found desirable. In the sluiceway at Watauga, piezometers have been provided in the baffle in front of the Howell-Bunger valves in the bottom of the 34-foot-diameter tunnel downstream from the baffle. Piezometers were also installed in the morning-glory spillway at Watauga. In the high head plants there are piezometers on either side of the head gates

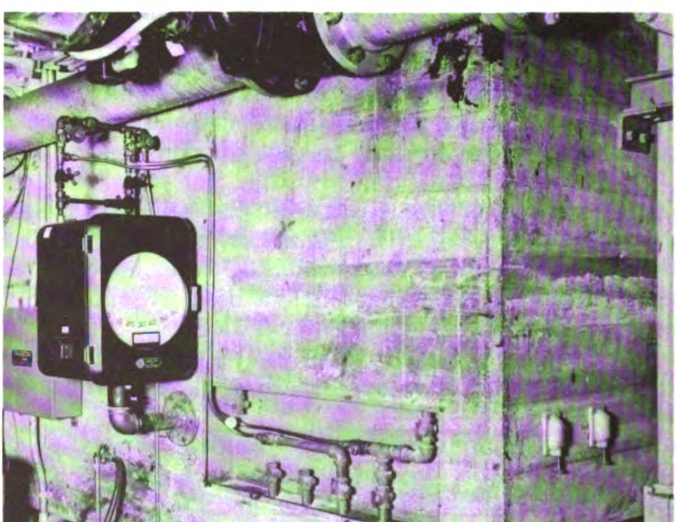

FIGURE 329.—*Turbine discharge flowmeter and piezometer cabinet—Cherokee.*

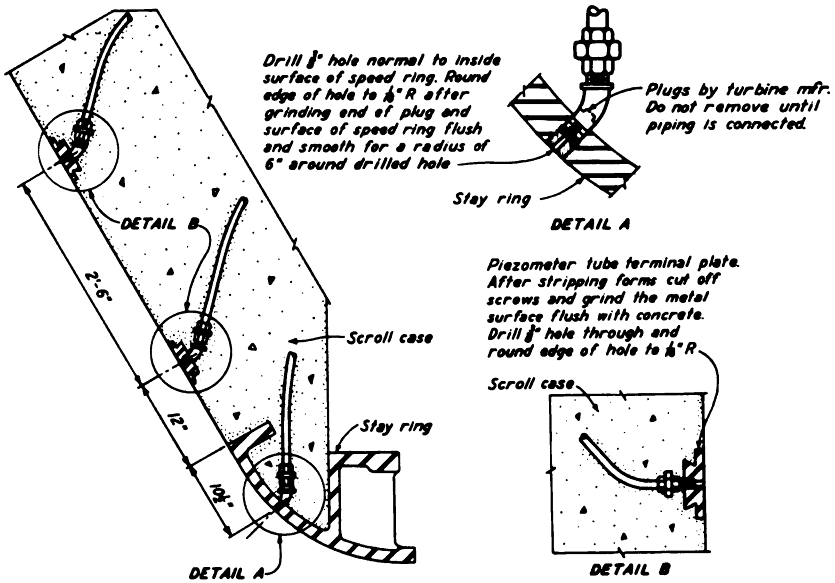

FIGURE 330.—*Typical piezometer connections to scroll case.*

connected to pressure differential switches to prevent operation of the head gates when the penstock is empty.

Piezometer lines are generally ¾-inch copper tubing, terminating in boxes set in the floor or gallery walls for easy access. Brass cocks are installed on each line in these boxes. The points of connection, if in concrete, are provided with brass plates. Connections to steel scroll cases or penstocks are provided with brass plugs drilled and ground flush with the inside surface. Figure 330 illustrates typical scroll connections.

During World War II, when copper tubing was unavailable, wrought-iron or steel pipe was substituted for copper tubing in some instances.

Miscellaneous instruments

At Ocoee No. 3 a recorder was installed to record the pH of the river water entering the turbine scroll case. Copper mining operations on the Ocoee River discharged large amounts of sulphuric acid wastes into the river resulting in the water flowing through the turbine having a pH as low as 4.5. This highly acid water was believed to have accelerated normally expected cavitation of the Ocoee No. 3 cast-steel turbine runner and it had apparently caused rapid deterioration after three month's operation of the new cast-iron turbine runners containing 2½ percent nickel installed at Ocoee No. 1. TVA in 1943 instituted an extensive testing program covering the effects of highly acid river water such as obtained at these plants on different types of metals and alloys. The pH recorder installed at Ocoee No. 3 provided information necessary to this testing program.

Pressure differential switches have been provided in some plants, interlocked with the gate-operating mechanism to prevent opera-

tion of the head gates in case the penstock is empty or an unbalanced pressure across the gate exists. Similar switches are also provided across the main raw water strainers in remote-controlled plants and connected to sound an alarm or annunciator in case the strainers become clogged.

Differential pressure switches have also been installed on butterfly valves and interlocked with the operating mechanism to prevent operation of the valve when the penstock is empty or a differential pressure too high for safe operation exists.

Excess velocity switches operated from Pitot tubes are also provided in penstocks equipped with butterfly valves to close the valve in case of failure of the turbine wicket gates or a break in the penstock which would cause a high water velocity and loss of water from the reservoir.

Each hydro plant is equipped with a station barometer and a thermometer to record outdoor meterological conditions.

Chapter 17

MISCELLANEOUS STRUCTURES AND PROJECTS

In addition to the structures and facilities required for the TVA-built hydro plants and unit additions, a variety of structures and projects were also required as a part of or as a result of TVA's overall hydro project program. The designs for the mechanical features of these structures and projects were handled by the Mechanical Design Branch along with its hydro plant design program, and it is felt appropriate that the more important of them be covered in this report. This chapter is included for that purpose. It discusses mechanical design features of structures and projects incident to backwater protection and malaria control, of construction camps and villages, of public facilities required principally as a result of recreational development brought about by the creation of the lakes, of river terminals built in the interests of navigation development, and of buildings required to house equipment for maintenance of reservoir lands and landscaped areas.

BACKWATER PROTECTION

Whenever a dam and reservoir are constructed within a developed area for a hydro plant, the backwater from the dam sometimes encroaches upon some established public or private facility. The simplest solution to this problem is to buy the property. This is always done in the case of flooded farm or other lands. However, when roads, railroads, water supplies, and sewerage systems are involved it is not only undesirable but almost impossible to eliminate them. Roads and railroads are consequently relocated to higher ground, and bridges built to provide facilities equal or better than those existing before the reservoir existed. Likewise, water-works and sewerage systems must be rebuilt on higher ground or if this is impractical completely different water sources and disposal methods substituted.

Occasionally the work to be replaced was obsolete or outgrown. In these cases improvements or enlargements were incorporated in the replacement with the owners paying the difference in cost between the hypothetical reproduced project and that actually constructed. Close legal and engineering coordination between the owners and TVA was always of prime importance before the work was started. When existing facilities were replaced the owners always assumed full responsibility for their operations and upkeep after a short agreed upon period of readjustment.

There were instances, however, which required backwater protection works where there were no existing facilities. In most of these cases TVA was obligated to operate and maintain the protection works in perpetuity. Examples of this are Dandridge on

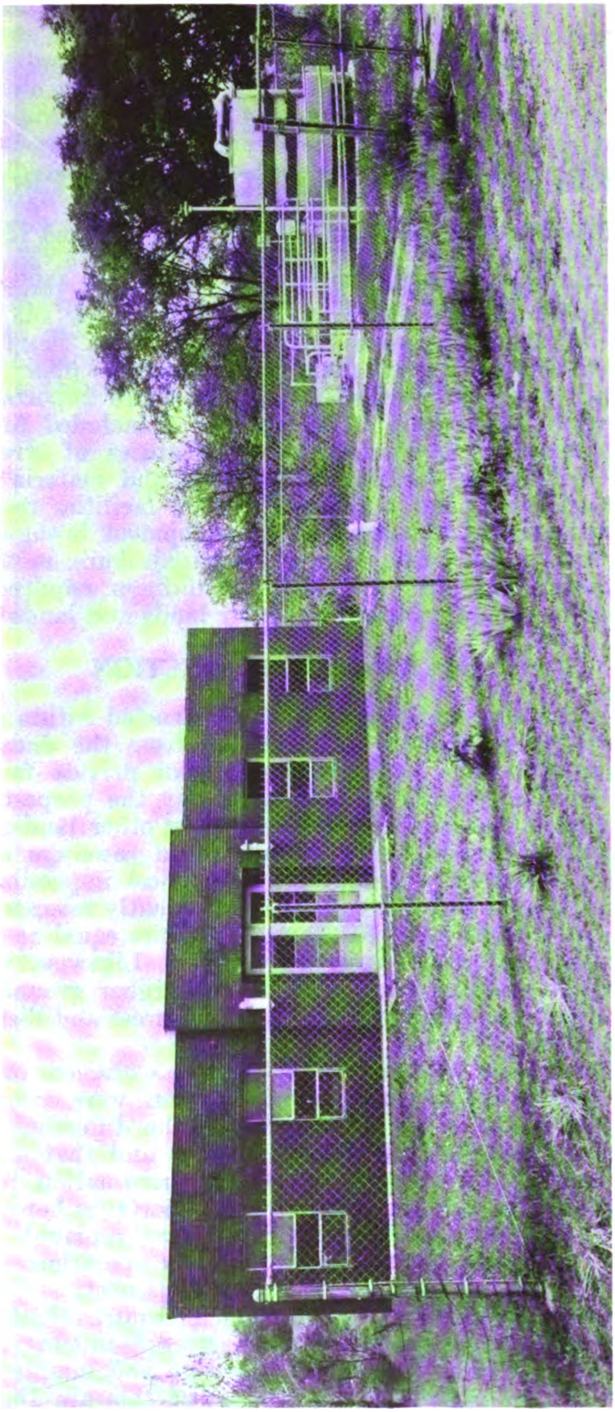

FIGURE 331.—*Water treatment plant—Jefferson City, Tenn.*

Douglas Reservoir, Kingston on Watts Bar Reservoir, and Big Sandy on Kentucky Reservoir. All are similar in that a reservoir flooded a portion of the valley in which the community lay, and the flooded portion was considered of too great importance to purchase outright. A dike was built across each valley, storm drains were installed to carry by gravity to the reservoir all water which was above the elevation of the top of the dike, and all drainage and sewage which would not flow naturally was pumped out. These pumping stations, drains, and dikes were designed, built, and are operated continuously by TVA.

Following are brief descriptions of four reasonably typical types of backwater protection projects: the spring supply, softening and filtration plant for Jefferson City, Tenn.; the adjustments to the outfall sewers of Knoxville, Tenn.; the storm water and sewage pumping station for Dandridge, Tenn.; and the raw water supply for the Southern Railway Co. at Leadvale, Tenn. At the end of each typical project description, other similar projects are identified.

Waterworks adjustments—Jefferson City, Tenn.

The water supply for this city was obtained originally from a spring which would have been flooded during periods of maximum water levels in Cherokee Reservoir. This supply was abandoned and a new supply developed from Mossy Creek Spring which is about ½ mile east of the city limits and above all reservoir levels. Figure 331 shows a general view of this plant.

The original abandoned system had no other treatment than chlorination. This, plus the necessary high lift pumps, was all that was necessary because the spring water was not excessively hard nor turbid. The new supply from Mossy Creek spring was very hard with hardness reaching 350 parts per million during periods of dry weather. Following heavy rains the water was also too turbid for use without treatment. Therefore, to substitute an equal system it was necessary to provide softening and clarification. The system provided reduces the hardness to 75 parts per million.

The new waterworks consists of the spring improvements, a lime softening and rapid sand filter plant, chlorination, necessary pumping equipment, and connections to the existing distribution system. The plant has a design capacity of 450 gallons per minute. All vegetation was cleared from the spring and an earth dike and rock overflow section built around it at the same height as the original normal flow levels so as not to disturb the natural flow conditions. The whole area was fenced for sanitary and physical protection. Two 450-gallon-per-minute at 46-foot head horizontal, centrifugal, motor-driven pumping units are installed in a pumphouse adjacent to the spring. These pump the raw, hard water to the softener tank. The water is strained at the pump suction and a constant rate of flow maintained by a raw water rate controller located in the common discharge of the low lift pumps. One of the pumps is a spare.

The softener consists of a vertical 21-foot 6-inch-diameter cylindrical concrete basin, a cone-type inner steel shell, a motor-driven agitator, and a coke tray aerator. Water from the low lift pump is discharged into the aerator and flows by gravity from it into the

bottom of the basin. The aerator accomplishes some softening by CO_2 removal. The major portion of the softening is accomplished by the addition of hydrated lime to the effluent of the aerator. The lime reacts with the soluble bicarbonates to form the insoluble carbonates. Alum is also added with the lime as a coagulant. Dry chemical feeders located in the adjacent purification building deliver the chemical solutions by gravity through pipes to the lower part of the softening basin. At this point the water is agitated to obtain a thorough mixture of chemicals and passes upward into the steel cone area. The top of the steel cone is perforated with seventy 1-inch holes around the periphery to control the flow of water out of the cone into a collector trough which directs the flow of settled, softened water to the filters. A sludge concentrator is built into the bottom of the steel cone in which the sludge accumulates. It is blown out at periodic intervals by hydrostatic pressure as controlled by a solenoid-operated valve in the drain line working in conjunction with a time clock.

Two rapid-sand, gravity filters each of 110-square-foot-area are rated at 225 gallons per minute each. The filters have 30 inches of filter sand supported by graded layers of gravel and underdrained by a perforated pipe grid. Each is independent of the other, and the rate is controlled by rate controllers with rate-of-flow and loss-of-head gages. The control valves are hydraulically operated and controlled by four-way valves on control tables. The effluent from the controllers flows to a 57,000-gallon clearwell located in the substructure of the purification building.

Immediately preceding the flow of water into the clearwell, it is sterilized by chlorine. This is fed into the pipe by a gas chlorinator of the manually controlled, visible vacuum type.

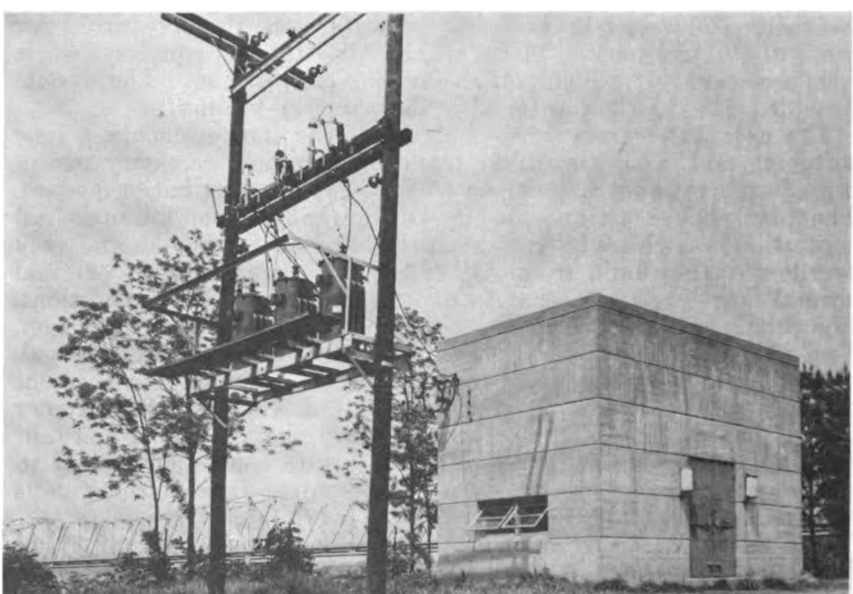

FIGURE 332.—*Water intake and pumping station—Morristown, Tenn.*

Three motor-driven, horizontal, centrifugal pumping units are located over the clearwell. Two are 500-gallon-per-minute units for pumping treated water into the city distribution system. One of these pumps was transferred from the abandoned city waterworks. The other was purchased new, and its design rate is at a discharge head of 220 feet. The third pump is a 2,100-gallon-per-minute at 40-foot head unit for washing the filters. An orifice-type flowmeter, with electrical integrator, indicates and totalizes the flow of water leaving the plant.

About 1 mile of 10-inch, cement-lined, cast-iron pipe was furnished and laid between the purification and pumping plant and the existing distribution system in the city.

The complete waterworks system was designed for manual operation. After a period of preliminary operation by TVA it was accepted by the city and operation and maintenance remains the responsibility of the city.

Similar waterworks adjustments were made by TVA as a result of backwater interference with existing facilities at the following places:

Owner	*Reservoir*
Town of Big Sandy, Tenn	Kentucky
Mead Paper Co., Harriman, Tenn	Watts Bar
Kingston, Tenn	Watts Bar
Harriman, Tenn	Watts Bar
Rockwood, Tenn	Watts Bar
Dayton, Tenn	Watts Bar
Teas Extract Co., Chattanooga, Tenn	Hales Bar
Knoxville, Tenn	Fort Loudoun
Morristown, Tenn. (fig. 332)	Cherokee
Rogersville, Tenn	Cherokee
Dandridge, Tenn	Douglas
N.C. & St. L. R.R., Johnsonville, Tenn	Kentucky

Sewerage system adjustments, Knoxville, Tenn.

The following sewerage adjustments were made by TVA in 1941 and 1942 during construction of Fort Loudoun Dam. The city of Knoxville subsequently constructed a sewage plant for treatment of these wastes and placed the plant in operation in 1955.

Backwater from Fort Loudoun Reservoir flooded most of the outfall sewers in Knoxville, Tenn., which necessitated rebuilding those portions adjacent to the reservoir in order to raise all except the outlets above the normal flow line of the reservoir. There were 28 outfall sewers on the north side of the lake and 6 on the south side. Of these, 18 on the north side and all on the south side required adjustment. Two of those on the north side were combined sewers; all others were sanitary sewers.

To comply with State health department requirements the outlets of all sewers were located between 5 and 10 feet below low water level in the reservoir. This required steep sewer grades between the last manhole on the elevated sewers and the outlet. To resist the eroding action of high velocity flows practically all the rebuilt sewers in these sections were of cast-iron pipe. At a few places in the new system, it was necessary to carry the raised sewers across creeks or other low spots on concrete piers. These sections also

were composed of cast-iron pipe. Special construction methods were used under railroads, roads and heavy fills, and on unstable ground. These methods consisted of laying the pipes in concrete cradles, encasing the pipe in concrete, supporting the pipe on piles or concrete mats, or combinations of these methods.

A total of 47,580 feet of main sewers were rebuilt. In addition about 1,000 feet of 4- and 6-inch pipe extensions or reconnections of existing house connections to these sewers were made. The lengths of main sewers by sizes and types of pipe are as follows:

Size in inches	*Length in feet*
Nonreinforced concrete sewer pipe:	
6	455
8	2, 976
10	2, 591
12	6, 615
15	4, 230
18	1, 595
21	3, 201
24	5, 347
Reinforced concrete sewer pipe:	
27	1, 096
30	4, 935
36	553
42	3, 280
48	4, 112
72	1, 096
Cast-iron pipe:	
8	681
10	153
12	1, 695
14	857
16	71
18	90
20	302
24	369
30	1, 158
36	122

In addition to the pipe listed above the necessary cast-iron and concrete sleeves, wyes, tees, curves, reducers, and other fittings were also installed. All of the pipe was purchased new except for 256 feet of 24-inch cast-iron pipe which was salvaged from the old system.

There were 232 new manholes required on the new alignments and several on the old system required alterations at connecting points. Most of the manholes were of standard brick construction, but many special types of reinforced concrete, or concrete and brick were required at special junctions. Manholes were installed at all junctions of main sewers and at all but minor changes in grade and alignment. In accordance with the standards of the city of Knoxville, all manholes were equipped with wrought-iron steps and cast-iron manhole frames and covers. About half of the manhole frames and covers was salvaged from abandoned manholes on the old system; all others were new.

All house services originally connected to the old sewers were reconnected to the new system, and plugged pipe stubs were installed at suitable intervals along the new pipes for future service connections. Many of the large abandoned sewers were discon-

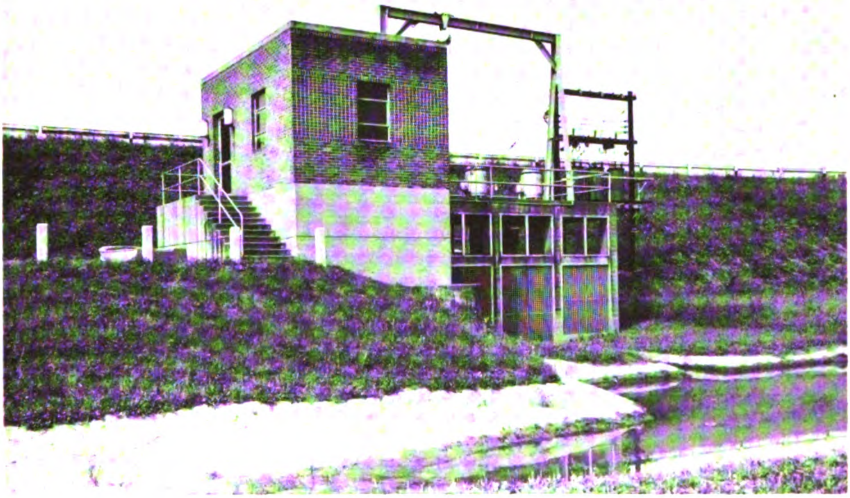

FIGURE 333.—*Sewage and storm water pumping station—Kingston, Tenn.*

nected and left in place at the request of the city of Knoxville for possible future use as storm water or industrial sewers.

Similar sewerage system adjustments were made by TVA as a result of backwater interference with existing systems as follows:

Owner	*Reservoir*
Savannah, Tenn	Kentucky
Chattanooga, Tenn	Hales Bar
Fulton Sylphon Co., Knoxville, Tenn	Fort Loudoun
Dandridge, Tenn	Douglas
Jefferson City, Tenn	Cherokee
Rogersville, Tenn	Cherokee
Morristown, Tenn	Cherokee
Murphy, N. C	Hiwassee
Bryson City, N. C	Fontana
Kingston, Tenn (fig. 333)	Watts Bar
Decatur, Ala	Wheeler

Drainage system adjustments—Big Sandy, Tenn.

Most of the town of Big Sandy, Tenn., is at or above elevation 370, and no structures are on ground below elevation 365. However, the maximum probable flood on Kentucky Reservoir will reach elevation 375 and without protective structures the town would be seriously damaged at such a flood stage. It proved more economical to protect the town than to purchase the area subject to flooding. The backwater protection consists of a dike, drainage ditches, and a pumping station, a view of which is shown in figure 334.

The dike was placed across the valley between the town and the reservoir with top of dike at elevation 385. Paved ditches were dug on both sides of the town to carry all natural drainage, including the main flow of Sugar Creek, around the town and the dike and into the reservoir by gravity. This left the lower part

FIGURE 334.—*Storm water pumping station—Town of Big Sandy, Tenn.*

of the Sugar Creek drainage area, consisting of about 140 acres between the ditches and the dike, not drained by gravity during high reservoir stages. A pumping station was built adjacent to the dike on the creek to drain this area, and all land below elevation 363 was purchased for pumping level fluctuations during heavy rain storms.

A 36-inch-square concrete discharge culvert beneath the dike connects the pumping station and the reservoir. A 30-inch flap valve and sluice gate is installed between the culvert and the pumping station which permits gravity flow to the reservoir whenever the reservoir level is below elevation 361. Inasmuch as normal reservoir level is elevation 359, the pumps operate infrequently.

Two electric-motor-driven, vertical, trash-type, pumping units of 750-gallon-per-minute capacity each at 17-foot head are provided. All water entering the pump suction pit passes through a creosoted wooden trashrack for removing coarse debris. Check valves and gate valves in the separate pump discharge lines prevent backflow from the reservoir. Operation of the station is entirely automatic with pumps controlled by separate float switches arranged to cut in at different water levels in the pump pit. The settings of the floats may be changed to alternate the lead pump and equalize wear.

Similar drainage system adjustments were made by TVA as a result of backwater interference with natural drainage as follows:

Location	*Reservoir*
Guntersville, Ala.	Guntersville
Kingston, Tenn.	Watts Bar
Dandridge, Tenn.	Douglas
General Shale Products Co., Knoxville, Tenn.	Fort Loudoun
Decatur, Ala.	Wheeler

Railroad water supply adjustments—Leadvale, Tenn.

The relocation of the Southern Railway to clear the backwater from Douglas Dam reservoir required the abandonment of the orig-

inal pumping station and water station. The original station was downstream of the confluences of the Pigeon and Nolichucky Rivers with the French Board River. These three streams did not mix until well below the pumping station but remained as distinct separate streams in the main channel. The pumping station was located in the clear Nolichucky stream and rarely picked up any of the paper mill polluted Pigeon River water or the very muddy French Broad River water. With Douglas Dam raising the water in the common channel, mixing of the three waters would occur above the site of the original pumping station. Therefore, in order to obtain equal water in the substitute station provided by TVA, it was necessary to go a considerable distance upstream to the south bank of the arm of the reservoir formed by the Nolichucky River.

The new facilities included a pumping station and intake near the Hamblen-Jefferson County line, a pipeline from it to the water station on the other side of the reservoir, two water storage tanks, and three water columns at the water station beside the railway tracks. One of the two tanks was furnished by the railway, inasmuch as there was only one in the original station; but additional storage was desired by the railway.

The pumping station consists of a vertical well 11 feet by 16 feet with bottom at elevation 970 and upper floor at elevation 1015, with house above. Two 10-inch, cast-iron pipes at two levels conduct water from the reservoir to the well. The lower one is protected with a screen at the intake. The lower line is 420 feet long and is below the lowest reservoir stage; in fact a low riprap weir is installed just downstream of the intake so that water will enter the intake if any water is flowing in the Nolichucky River. The upper intake is about 100 feet long. Two vertical turbine pumps are installed in the well with motors on the elevation 1015 floor, and discharge and valves located above a subfloor at elevation 1005. The pumps each have capacities of 500 gallons per minute at 100-foot total dynamic head.

The pumps discharge through a 10-inch, cast-iron pipeline to the storage tanks. This line consists of approximately 7,500 feet of 10-inch, class 150 bell and plain end pipe and 900 feet of 10-inch, class 150 mechanical joint pipe. The latter is used for crossing the bed of the French Broad River. Air release valves are installed at three high points in the line, and blowoff valves at three low points. The main pipe and valve arrangement in the pumping station is such that the lower intake line can be flushed from the full intake well or from the storage tanks or pumps. The former method will produce a large flow of low-pressure water, and the latter two methods a relatively small quantity of high-pressure water. These features were considered necessary to clear the intake of silt or other debris. A sand eductor is installed in the bottom of the pump pit with discharge through a 3-inch pipe out through the upper 10-inch intake pipe to keep the pit free of silt. A 15-horsepower, close-coupled centrifugal pump, with suction connected to the main station discharge pipe, furnishes operating water to the eductor. Accumulations of sand, silt, and small gravel in the pump well are successfully removed by periodic operation of this system. The river intake is provided with a heavy wire, 3-mesh screen to prevent

the entrance of large gravel, walnuts, and other trash which would clog the eductor or pumps.

At the water station a 12-inch, class 150 bell and plain end cement-lined, cast-iron pipe supplies water from the storage tanks to the three water columns. The storage tanks are 30 feet in diameter and 20 feet high, each having a capacity of 96,000 gallons. They are constructed of 3-inch-thick creosoted yellow pine, banded with 1-inch steel hoops.

The pumps are controlled by float switches in the storage tanks which start and stop the pumps as levels lower and rise. A selector switch in the pumping station is provided to alternate the pumps. One only is on automatic control; the other is a spare. A float switch is also installed in the pump pit for stopping the pump in case of low water in the suction well. This would only occur if the intake became plugged but is necessary to keep the pump from operating dry.

A similar water supply system was furnished the Illinois Central Railroad near Kentucky Dam because of relocation of the main line and the water station of this railroad. Also, at Johnsonville, Tenn., a well water supply was furnished the Nashville, Chattanooga & St. Louis Railway for not only a water station but also for potable water for a group of section houses.

MALARIA CONTROL

Before the advent of TVA the general area surrounding the present Kentucky Reservoir was one of the worst malaria sections in the United States. The TVA instituted numerous measures for the control of the *Anopheles quadrimaculatus* mosquito, which has resulted in practically complete elimination of malaria from the Tennessee Valley. These measures include spraying swamps and backwaters with larvicidal oil, dusting wide areas with DDT by airplane, screening of doors and windows of houses on the area, and fluctuating the levels of the main-river reservoirs weekly by 1 foot. The latter measure strands and kills the mosquito larvae before they develop into mosquitos.

Many low-lying areas within the Kentucky and Wheeler Reservoirs would be periodically flooded from reservoir backwater unless protective measures were taken. The swamps and extensive ponds possibly without control would develop into ideal mosquito-breeding areas requiring costly malaria control operations. The cost of diking, drainage, and pumping could not be justified on the basis of malaria control alone. Other considerations, however, more than justified their costs. Most of the low areas were covered with trees and several miles of relocated highway and railroad embankments traversed the areas. If the areas were not protected the trees would be killed by flooding. However, with no trees to act as breakwaters the road and railroad embankments would have to be riprapped to protect them against wave action. The cost of riprap and tree removal was evaluated to be more than the pumping costs, and the great benefits of cheap malaria control were realized. Pumping is of necessity an intermittent operation which causes a fluctuating level in the drained areas thus stranding mosquito larvae in a simi-

lar fashion to that in the main reservoir. In addition, much of the area was suitable for agricultural purposes if a calculated risk was taken that every few years a crop might be lost because of emergency flooding.

On Wheeler Reservoir another consideration was involved. Through cooperation with the Fish and Wild Life Service, one pumping station was designed so that during certain nongrowing periods the flow could be reversed; that is, water pumped from the reservoir into the low-lying areas and thus flooding them. These act as refuges for wild aquatic birds.

Kentucky Reservoir pumping stations

The areas involved were isolated from the reservoir by dikes, with pumping stations adjacent to them to pump accumulated water to the reservoir. Gated sluiceways were combined with the pumping stations, or as separate structures through the dikes, to allow gravity flow to the reservoir during low reservoir levels. The dikes protect the areas against flooding up to elevation 359, which is the normal reservoir flow line. During the mosquito-breeding and tree-growing seasons, the reservoir levels are usually below this level. High water occurs normally only during the winter months. It is interesting to note that during the first year of operation unusually high summer reservoir levels required pumping out the unwatered areas several times because the dikes were topped.

During winter the gates in the dike sluiceways are opened and water levels fluctuate together on both sides, or over the dikes. In the spring when the water level drops to elevation 359 or below, the gates are closed, the pumps all started, and the areas dewatered. During the winter months when the areas are flooded the trees are in a dormant state, and many species are but little affected. After the pumps are once started, they operate automatically on float switch control until the autumn when the pumps will be shut down manually, the sluice gates opened, and the cycle repeated. The pumps are of such capacity that it will take between two and four weeks of continuous operation to unwater the areas initially with all pumps operating. After the initial drawdown, under normal rainfall conditions, one pump in each station running intermittently will keep the areas dewatered. A typical cross section of a dewatering project is shown in figure 335.

There are eight dewatering stations on the Kentucky Reservoir area. Two of these were near existing power transmission lines at the time of construction, so the pumps were made electric-motor-driven. All others were in such isolated areas that it was more economical to operate the pumps with gasoline-engine power. In 1954, however, the Duck River station with four pumps was partially converted to electric power by substituting a 200- and a 100-horsepower motor for two of the engines. The pumps are all vertical, wet-pit, propeller or mixed flow types, with horizontal discharge through flap valves to prevent back flow. The schematic arrangement of a typical gasoline-engine-driven pumping station is shown in figure 336. Tables 15 and 16 present pertinent data concerning the pumps, motors, engines, and equipment for these stations.

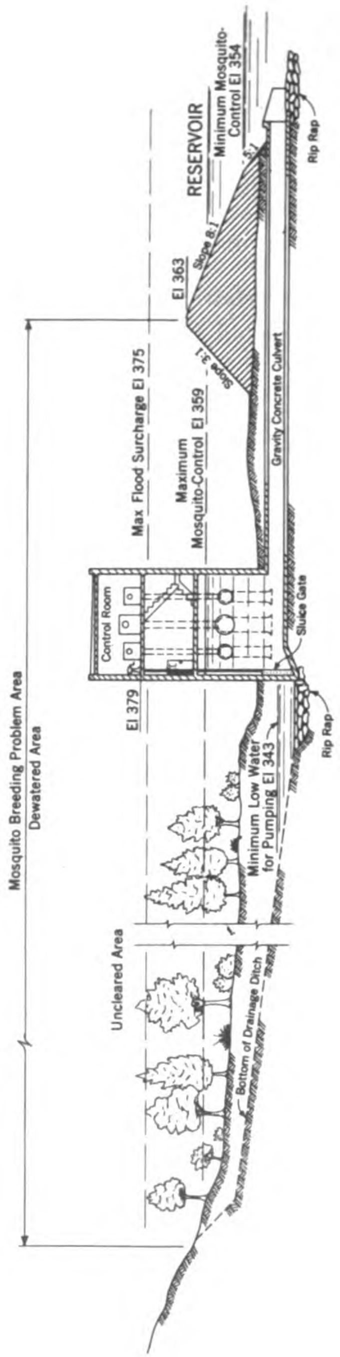

FIGURE 335.—*Cross section of typical dewatering project*

TABLE 15.—*Motor-driven dewatering pumping station data—Kentucky Reservoir*

Station	Number of pumps	Capacity, g.p.m.	Head, feet	Type	Flap valve and pump discharge size, inches	Motor, hp.	Speed, r.p.m.	Sluice gates	
								Number	Size, inches
West Sandy	4	50,000	6.25	Propeller	48	150	390	4	96 by 96
	2	25,000	12.0	do	36	100	495		
Camden	2	52,000	6.0	do	42	150	390	3	96 by 96
	1	45,000	12.0	do	54	200	390		
Duck River	1	49,500	4.0	do	48	200	440	2	96 by 96
	1	16,700	12.0	do	30	100	880		

TABLE 16.—*Engine-driven dewatering pumping station data—Kentucky Reservoir*

	Duck River	Big Sandy River	Perryville	East Perryville	Gumdale	Busseltown
Number of pumps	2	1	1	1	1	1
		1	1	1	1	1
Capacity, gallons per minute	52,000	15,000	12,000	8,000	9,000	9,000
		15,000	12,000	8,000	9,000	9,000
Head, feet	4.6	4.9	5.6	5.8	7.6	10.6
		7.9	10.6	8.8	9.6	12.6
Type	[1]	[1]	[1]	[2]	[2]	[2]
		[1]	[1]	[2]	[2]	[2]
Flap valve and pump discharge size, inches	48	24	20	16	16	16
		24	20	16	16	16
Full load engine, horsepower	179	75	62	41.5	61	62.5
		77	65	43.5	62	63.5
Engine speed, revolutions per minute	1,200	878	915	1,008	964	1,006
		918	965	1,083	994	1,037
Pump speed, revolutions per minute	430	585	685	685	771	805
		612	740	722	795	830
Sluice gates:						
Number	2	1	1	1	1	1
Size, inches	96 by 96	72 by 72	48 by 60	48 by 48	48 by 48	48 by 48

[1] Propeller. [2] Mixed flow.

The motors for electric pumping stations are of the vertical low-speed, hollow shaft, weatherproof type and are located on an open deck, direct-connected to the vertical shaft of the pumps, with all controls located in the building. All motors are equipped with strip heaters to protect the windings from condensed moisture when they are not in operation. All ventilation openings are screened with copper mesh to keep mud dauber wasps out of the motors. These insects built nests within the pumps during the first few months of operation, and this refinement became of utmost importance.

The gasoline engines are of the horizontal, multicylinder, radiator-cooled type located in the building with a horizontal flexible shaft extending from the engines through the building wall to a reduced-speed, hollow shaft, right-angle gear drive located on the open deck (fig. 337) with its vertical shaft direct-connected to the vertical shaft of the pump. The engine radiators are installed on the open deck with fan drive from pulleys on the stub shafts of the right-angle gear drives in order to dissipate the heat from the engine cooling water outside of the building. The engines' controls are designed to start, maintain, and stop the engines automatically

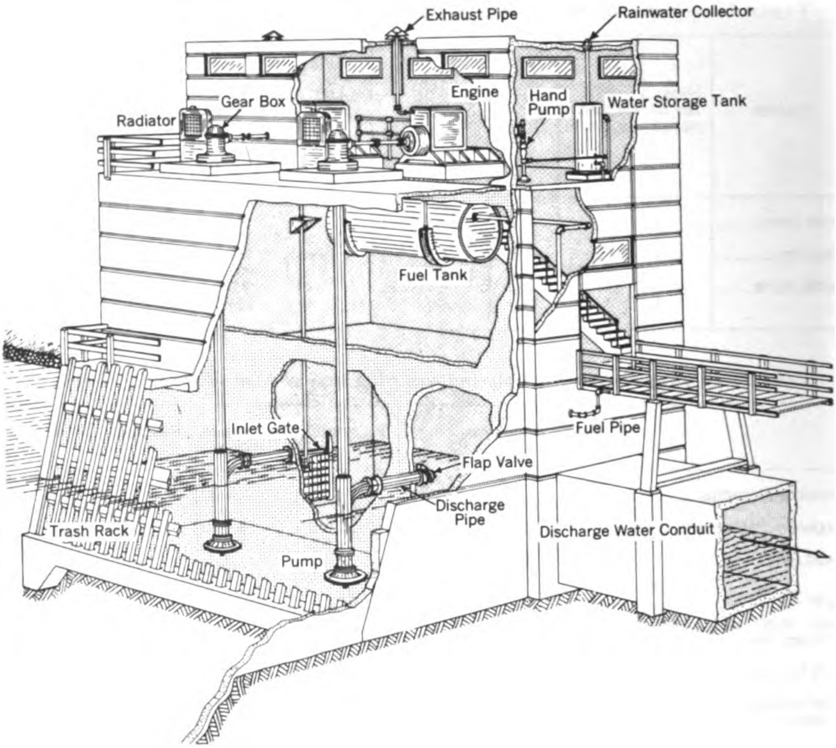

FIGURE 336.—*Schematic diagram of typical dewatering pumping station—Perryville, Kentucky Reservoir.*

as controlled by float switches. In actual operation, however, the engines are started manually, and the automatic controls stop them at low water or for some mechanical fault such as overspeed, overheating, low oil pressure, or fuel or ignition failure. Figure 338 shows a typical engine installation.

Gasoline storage tanks are suspended beneath the engine room floor and have approximately 9 days' fuel supply for continuous operation of all engines. For the Duck River and Big Sandy River stations, gasoline is delivered by tank truck to a point on the access road where a small gasoline-engine-driven pump delivers the gasoline from the truck to the station storage tanks. At all other stations excessively long supply pipelines would have been necessary and so gasoline is delivered by barge and pumped to the station tanks by means of pumps on the barge. Water for replenishing the radiator cooling water is obtained from a storage tank supplied by rain water from the roof leaders. An auxiliary emergency supply may be obtained by pumping water from the sluiceways to this tank by means of a hand pump.

On all stations except Camden, which is shown in figure 339, the sluiceways are controlled by rising-stem sluice gates operated by two-speed, hand-operated floorstands on the pump room floor. At the West Sandy Creek station, the floorstands are located on the

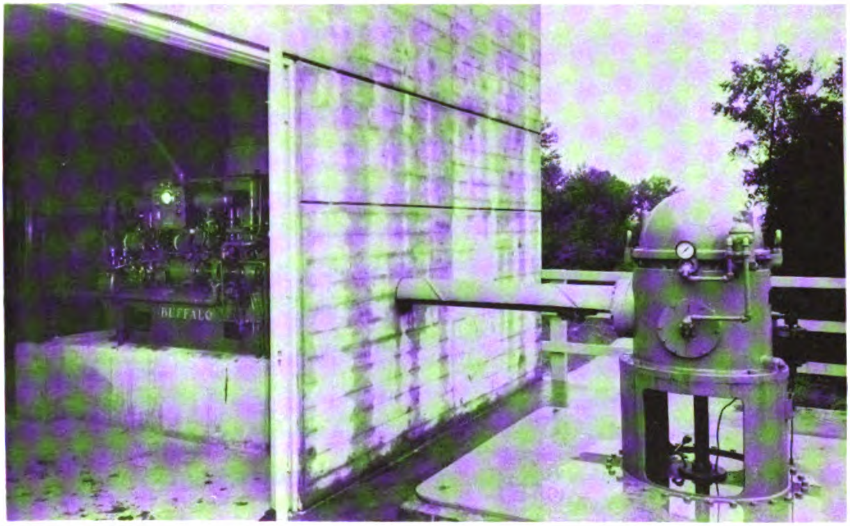

FIGURE 337.—*Typical dewatering station showing gasoline engine and right-angle pump drive—Duck River pumping station, Kentucky Reservoir*

open deck, and the gate stems are protected by stem covers. At the other stations the stands are inside the building, and the stems are left exposed. At Camden one sluice gate is located within the station, and two others are located in a separate sluiceway adjacent to the pumping station. These gates have their floorstands on the top of the dike and are completely submerged at high reservoir levels. These gates, therefore, are of the nonrising-stem type with floorstands equipped with watertight stuffing boxes to protect the stems from silt-laden water at these times.

The top decks of the pumping stations on which the motors or engines are located are at elevation 379 or above. This protects

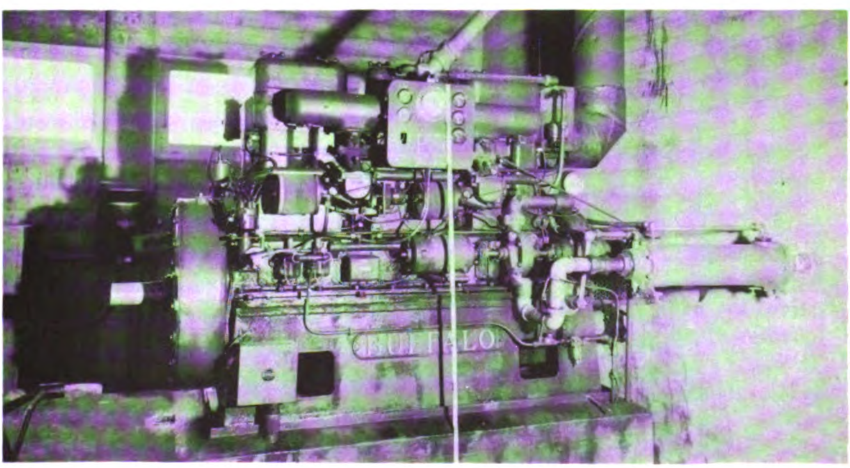

FIGURE 338.—*Typical gasoline engine installation for dewatering station—Kentucky Reservoir.*

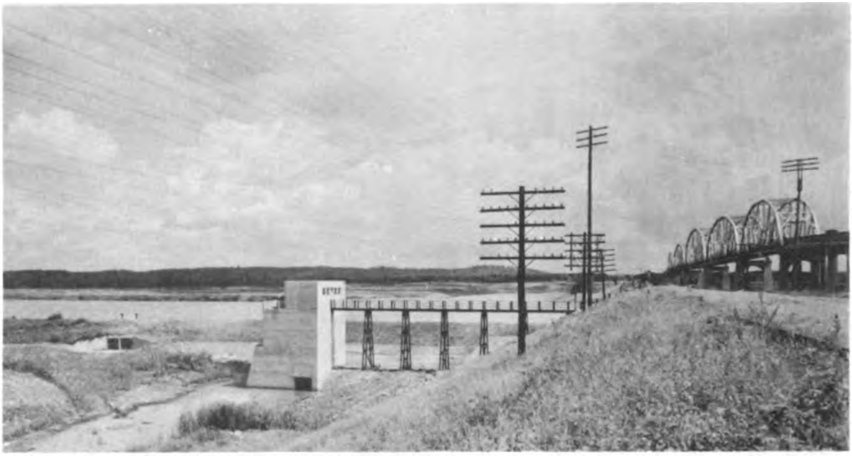

FIGURE 339.—*Motor-driven pumping station—Camden, Kentucky Reservoir.*

these features from danger of all probable floods. This feature is clearly seen in figure 340 showing the Busseltown station.

Wheeler Reservoir pumping stations

Two stations are located on the Wheeler Reservoir area with pumps and operation similar to those on the Kentucky Reservoir, but the station design is different. No flap valves are used on the discharge, but the discharge is carried down to a bellmouth below low water to take advantage of the siphon effect and reduce the head on the pumps. The siphons are prevented from acting in the reverse direction when the pumps stop by means of solenoid-operated vent valves on the high points of the discharge pipes. These valves are normally open and only closed when they and the pump

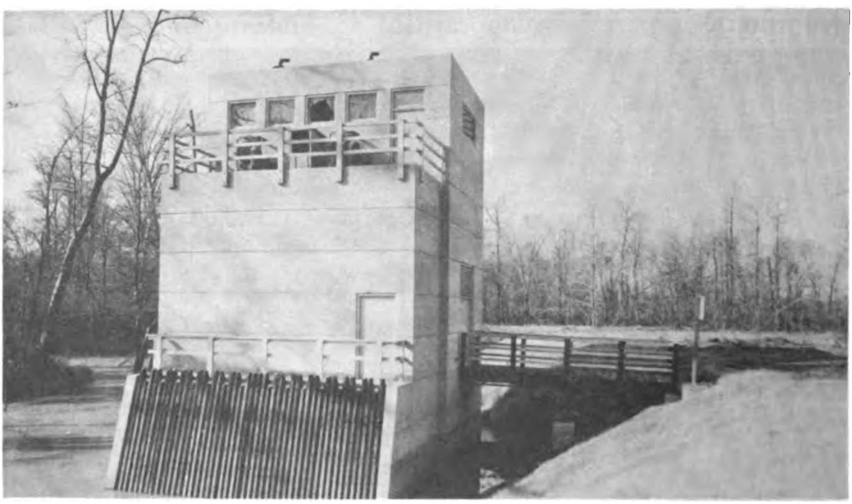

FIGURE 340.—*Gasoline-engine-driven pumping station—Busseltown, Kentucky Reservoir.*

drivers are energized. The Rockhouse Slough pumping station has gasoline-engine-driven pumps, and the siphon vent valves are direct-current-operated from the engine battery system. The Harris-Sweetwater station is entirely electric. Upstream and downstream views of this station are shown in figure 341.

The Rockhouse Slough station is unique in that one of the two pumps is arranged to pump in either direction. This pump is located in a separate pit with water supplied from either the reservoir or the dewatered area as controlled by sluice gates. When requested by the Fish and Wild Life Service, water may be pumped from the reservoir to the previously unwatered area to serve as a wild aquatic fowl refuge.

Operating bases

Floating docks, lockers, and boat slips are provided at 10 locations for servicing small boats used for spraying larvicidal oil for mosquito control. There are steel storage tanks for gasoline and larvicidal oil at each base. Different provisions are made for gasoline and oil delivery at some bases; both tank truck and barge delivery are necessary depending upon accessibility of the bases. Figure 342 shows the base at Camden which is typical of all except Big Sandy. A maximum lake level variation of 30 feet requires that gasoline and oil lines be equipped with flexible hose between docks, gang planks, and floating docks. A well with hand pump for drinking water and a privy is provided at each base. At Big Sandy there are a central repair building, warehouse, and boat storage yard. A general view of this base is shown in figure 343.

CONSTRUCTION CAMPS AND VILLAGES

During the construction period at all major hydro projects certain minimum facilities for personnel are required, including an administration building, hospital, personnel office, and cafeteria. At isolated projects additional structures are necessary such as dormitories, recreation halls, family housing, trailer parking areas, other inducements for employment and employee comfort, and occasionally even jails. All these facilities require the usual water power, light, heat, and sewerage utilities. The design of water supplies, treatment plants, and sewerage systems together with the plumbing and heating systems has generally been the responsibility of TVA's Mechanical Design Branch. Many of the buildings, together with their plumbing and heating equipment, were developed as standards and the same drawings were used on many projects, in fact the same buildings were often moved from project to project.

In every case, however, the water supply, treatment and distribution, and sewerage systems presented different problems. In all cases the requirements of the health department of the state involved were met. As a minimum, chlorination was provided for the water supplies but usually a treatment plant including chemical feed, mixing tanks, settling tanks, filters, clearwell, high head pumps, elevated storage, and a grid distribution system were necessary. The treatment plants were always designed for temporary use and wood stave tanks were used throughout. At Fontana, the

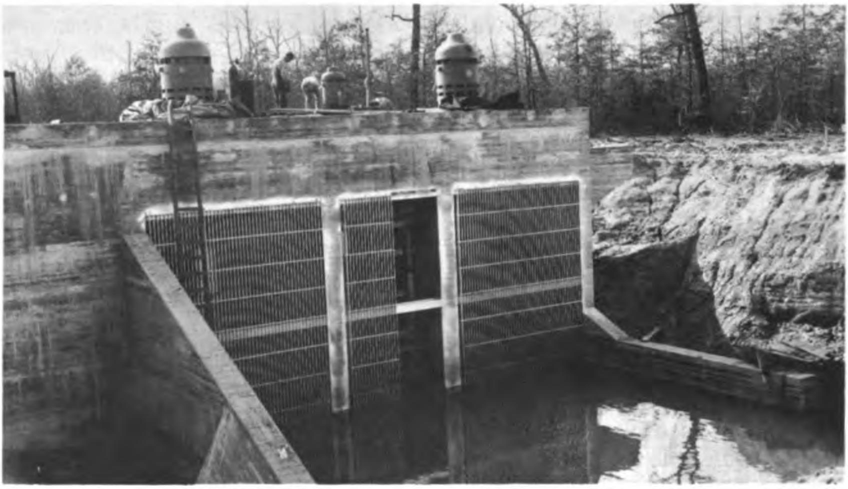

FIGURE 341.—*Upstream view, top, and downstream view, bottom. of Harris-Sweetwater pumping station—Wheeler Reservoir.*

water-treatment plant was taken over by the operator of the construction village when it was converted to a resort, at which time the plant was operating satisfactorily.

The sewerage systems usually consisted of plain concrete sewers leading to either a septic tank or, where conditions permitted, to untreated outfall to the main river. In many cases sewer grades exceeded accepted standards but, inasmuch as they were for temporary use and the standards were established to prevent excessive erosion, economy ruled.

Adequate but inexpensive plumbing fixtures were used in all construction buildings. Hot water was supplied from suitably sized storage tanks having thermostatically controlled electric immersion heaters. All piping was galvanized steel with galvanized malleable-

iron fittings. Heat was furnished by electric heaters. These were usually of the portable type but some built-in units were used.

PUBLIC FACILITIES

Picnic areas and marinas

Immediately following impoundment, the lakes behind the TVA-built hydro dams became popular for boating and other water sports, and the lake shores as picnic areas. Facilities for better public enjoyment of these features quickly became obvious and TVA made them available. Boat docks and concession buildings for leasing to private enterprise were built at picturesque spots not far from the access roads to the dams. Likewise picnic areas with tables, benches, fireplaces, walks, and parking areas were established.

All these facilities required potable water and sewerage. In all cases the sites were close enough to the powerhouse or source of water supply so that connections were made to the permanent project water supply system. In most cases the sites were too high or far away to provide adequate fire protection without booster pumps. Where economically feasible, fire protection was provided with fire hydrants located at strategic points. Otherwise, a calculated risk was taken and none provided. Frostproof or manually drained drinking fountains and small hydrants for filling cooking utensils were conveniently located throughout picnic areas. All marinas and picnic areas were supplied with simple but adequate toilet buildings with sewage usually disposed of by means of septic tanks and underground drainage systems. At Fontana and Kentucky sewage was easily connected into the project sewerage system. Very little use is made of these facilities during the winter and consequently no heating is provided and the buildings are locked and piping drained to prevent freezing during extremely cold weather. Figure 344 shows the Chickamauga Marina, figure 345 shows the Bee Cove Harbor at Fontana, and figure 346 shows the picnic area, shelter, and toilet building at Kentucky Dam.

Comfort stations and safety services

Bank fishing became a very popular sport downstream from most of the main-river dams. Several hundred fishermen were counted

Figure 342.—*Malaria control operating base showing floating dock—Camden, Kentucky Reservoir.*

FIGURE 343.—*Malaria control base showing warehouse and shop buildings—Big Sandy, Kentucky Reservoir.*

frequently along the banks for short distances downstream from the turbine discharges. As a result, many nuisances were committed. Privies were built but soon proved entirely inadequate. Toilet buildings were then constructed principally for the use of the fishermen. Most of them were located along the bank on the flood plain and were of necessity so constructed that frequent submergence would do no harm that could not be remedied by later washing down with a hose. Frostproof water closets were installed in all buildings subject to flooding and they are open for use at all seasons.

Other public toilet buildings were built above the maximum flood elevation where this could be done and still be convenient for fishermen's use. In some cases an office for TVA public safety service employees was incorporated in the structures. For this type of building standard toilet fixtures were furnished and heat provided for comfortable year-round use. Figure 347 shows a construction view of this type of structure at Kentucky Dam.

In all cases, a waterline was extended from the permanent powerhouse system to supply potable water for all sanitary use. All

FIGURE 344.—*Aerial view of Chickamauga Reservoir marina.*

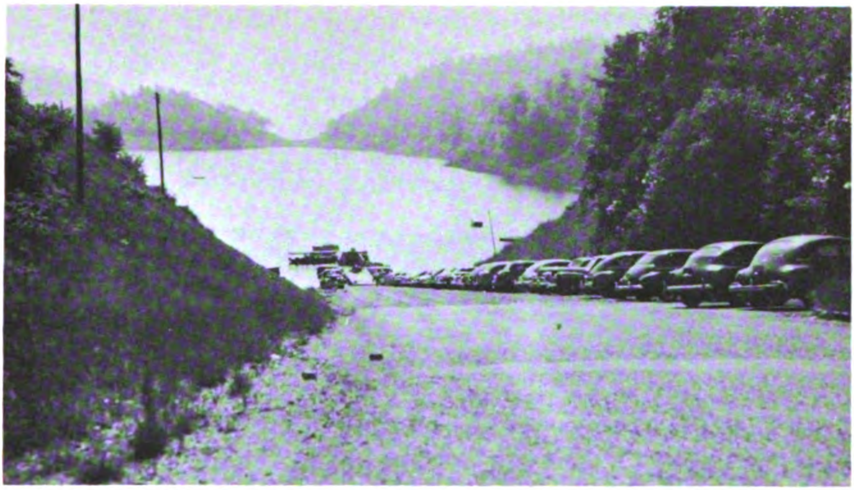

FIGURE 345.—*Public access to Bee Cove boat harbor—Fontana Reservoir.*

FIGURE 346.—*Public shelter and toilet building at picnic area—Kentucky Dam.*

sewage is treated in State health department approved septic tanks and underground drainage fields.

RIVER TERMINALS AND MAINTENANCE BUILDINGS

The Mechanical Design Branch was also responsible for the design of all piping, mechanical equipment, and sanitation work in river terminals built in the interests of navigation development and of buildings required for reservoir land maintenance purposes.

Public-use terminals on the Tennessee River were built by TVA at Knoxville and Chattanooga, Tenn., and Guntersville and Decatur, Ala. These terminals provide loading and unloading facilities, office, and storage for the greatly increased river traffic brought

FIGURE 347.—*Public safety service headquarters and public toilet building under construction—Kentucky Dam.*

about by completion of the 650-mile navigation channel from Knoxville to Paducah, Ky., where the Tennessee enters the Ohio River. Figure 348 shows the Knoxville terminal. The Chattanooga terminal has been sold and the other three are leased to private interests.

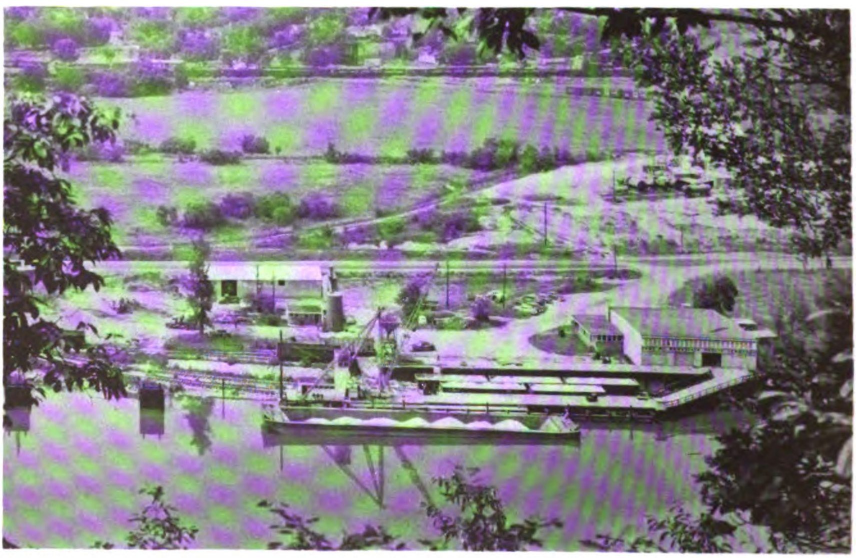

FIGURE 348.—*Public-use river terminal on Fort Loudoun Lake at Knoxville, Tenn.*

The majority of the hydro projects include a small building or structure to house the equipment and tools required by TVA's Division of Reservoir Properties in maintaining landscaped areas and reservoir lands which are under TVA jurisdiction. A typical structure of this nature is illustrated in figure 349, which shows the Douglas Dam maintenance building. In addition to office and storage space a few machine tools are provided for servicing equipment.

FIGURE 349.—*Reservoir properties maintenance building—Douglas Dam.*

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Chapter 18

SCHEDULES AND DESIGN PROCEDURE

Chapter 1 outlined the organizations of the Division of Design and its Mechanical Design Branch and their relationship to other TVA organizations and to the Corps of Engineers. As stated in that chapter, the principal function of the design division is to handle the detailed design of a project after its broad outline has been determined by the planning division. This involves furnishing the construction division with all required detail construction drawings and specifications, the preparation of equipment and material specifications for procurement through established procedures, participation in performance testing of the equipment, formulation of instructions required for operation of the plant and its equipment, and occasional inspection of the construction work in progress as necessary to ensure the carrying out of the design.

The Mechanical Design Branch, with particular regard to hydroelectric power projects, is responsible for the preparation of designs, drawings, specifications, and instructions for mechanical equipment and related systems. This includes hydraulic turbines and governors, turbine inlet valves, auxiliary power generators, passenger elevators, pumps, air compressors, oil purifiers, machine shop equipment, heating ventilating and air-conditioning equipment, water and sewage treatment and plumbing facilities, water fire-protection equipment and all related piping systems; the design of the foregoing equipment and facilities is discussed in the preceding chapters.

Working under the direction of the Chief Design Engineer and the technical staff, the design branches are required to coordinate designs, drawings, schedules, and procedures between themselves to ensure integrated and harmonious designs and orderly carrying out of the work. This coordination is accomplished by (1) the lead design branch developing the basic general layout of the dam, powerhouse, lock (if required), switchyard and other related structures. These arrangements are coordinated with the other design branches and technical staff engineers and are subject to approval of the Chief Design Engineer and the Chief Engineer; (2) by conferences for discussion of significant features of design and particular development of individual branch work with decisions being disseminated to all concerned by circulation of design memoranda, conference reports, diary notes, etc.; (3) by each design branch sending its drawings to the other design branches for review, checking, and coordination. This is generally known as "squad checking" and is done before the drawings are signed by the chiefs of the individual design branches and the Chief Design Engineer and prior to issuing the drawings to the construction division. This procedure ensures that all detailed features will fit together and

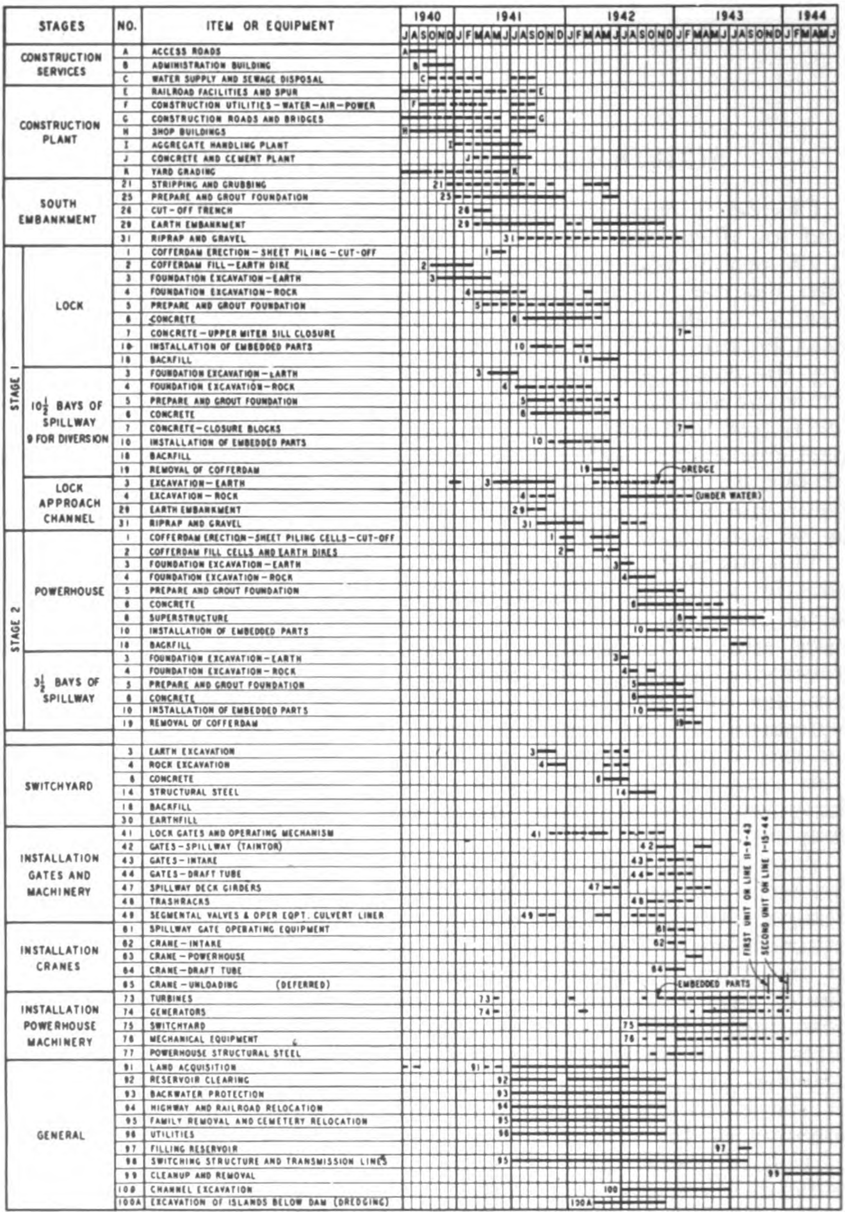

FIGURE 350.—*Construction schedule—Fort Loudoun.*

practically eliminates the possibility of conflict between the several phases of design work; and (4) by coordination of procurement and design schedules between the branches for compatibility and to ensure that the design work of each branch is being done in the proper time sequence.

Upon authorization of a major construction project the TVA Board of Directors instructs the Chief Engineer to proceed with

design and construction of the project. To enable orderly procedure, the major initial steps taken are: (1) preparation of construction schedule, (2) preparation of procurement schedule, and (3) preparation of design drawing schedule. These schedules are essential to proper organization of the work and their importance in this respect justifies the amount of time which is usually devoted to their preparation. These schedules are prepared in the order named as soon as possible after project authorization and determination of the general project layout.

SCHEDULES

Construction schedule

This schedule is usually initiated by the Construction Plant Branch under the direction of the Chief Construction Engineer. It is a bar line chart which sets forth the dates when all phases of the construction work related to the project must be started and finished to effect completion in time to meet predetermined generating unit operating schedules. A typical short form portion of the Fort Loudoun project construction schedule is shown in figure 350.

The operating dates for individual generating units, based on the requirements of the power system, are customarily established at the time of the project authorization. This requirement, within the limits of the magnitude of the project, usually sets the date for closure of the dam and in turn the completion dates for all phases of construction related thereto.

Major factors influencing the development of the construction schedule are the required speed of construction and the overall economy. During an emergency, such as wartime, when the needs of the power system are of paramount importance, economy must sometimes be sacrificed for speed of construction. Other factors influencing the construction schedule are foundation conditions, seasonal floods, time required by equipment suppliers to manufacture the equipment, delivery time of other materials, and, of course, the magnitude of the job. The latter items in a major multipurpose hydro project are often the controlling factors rather than the amount of time required by the major equipment suppliers to manufacture such items as the hydraulic turbines, generators, transformers, and other electrical equipment. The reverse is usually true for a steam electric generating plant where the project construction schedule is generally predicated upon the amount of time required by the turbogenerator, boiler, and major equipment manufacturers to design and build their equipment.

The construction schedule includes a breakdown of all individual features of the project such as the dam, lock, spillway, intake, embankments, powerhouse, switchyard, tailrace, and all miscellaneous structures. In addition it includes such related items as access roads and railroad facilities, construction plant services and utilities, land acquisition, reservoir clearing, backwater protection, and river channel improvement.

Before the construction schedule is completed it is coordinated with the Division of Design. The construction schedule serves as a basis for preparation of the procurement and drawing schedules

hereinafter discussed. Since the Division of Design is responsible for the preparation of the latter two schedules, it is imperative that the construction schedule be thoroughly checked for accuracy, timing, and the inclusion of all items. A carefully prepared detailed construction schedule which includes all important items and phases of the work will result in better coordinated procurement and drawing schedules which in turn are vital to overall accomplishment of the work.

Procurement schedule

After establishment of the construction schedule, the Chief Design Engineer requests the chiefs of the various design branches to prepare procurement schedules covering all items of equipment and material for which they are individually responsible. A portion of the Mechanical Design Branch procurement schedule for the Fort Patrick Henry project is shown in figure 351. This schedule lists each individual item of equipment and material required for every separate feature of the project. Opposite each item are shown the dates for requisitioning, awarding, and delivering the equipment or materials to the construction site. The delivery date of a particular item shown by letter "D" on the schedule is established according to the need for the item in the field to meet the requirements of the previously agreed upon construction schedule. Where the situation will permit, delivery dates are set one month ahead of the actual field requirement to allow for unforeseen manufacturing and shipping delays and to accommodate any possible advance in the construction schedule.

Working from the required delivery date, the award and requisitioning dates shown on the schedule by the letters "A" and "R," respectively, are set. In many cases the interval of time between the dates of award and delivery is dictated by the amount of time required by the equipment builder or material supplier to manufacture and effect delivery. During the emergency of wartime with attendant governmental controls and priorities this factor becomes a controlling one in the development of procurement schedules to meet anticipated long manufacturing and extended delivery times. In other cases the interval of time allowed between award and delivery is determined by the fact that award of certain equipment must be made at an early date in order that design information concerning the equipment will be available to the design engineers in time to prepare construction drawings and make other related procurements such as connecting piping, wiring, ductwork, and controls.

Sometimes the size and details of equipment are necessary to the determination of basic space dimensions and arrangement of structural features like the powerhouse and also the specification and procurement of handling and servicing equipment such as cranes and hoists. This factor is true to the extent that requisitions for major items of equipment such as hydraulic turbines, governors, and turbine inlet valves are usually issued immediately following project authorization, with invitations being sent out, bids received and awards made prior to the preparation of construction, procurement or drawing schedules. The detailed dimensions and types of

NO.	LOCATION ..... POWERHOUSE AND CONTROL BAY ITEM	CIVIL	MECH	ELEC	ARCH	1952												1953												REMARKS Design Ref No.
						JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
361	Turbine and Governor		DS	M		(Requisitioned 1-31-51 & Awarded 5-11-51)																						#2		H21M-1
362	D.T. Liner and Bolts		DS	M													D1		D2			Units on line (Comm)								H21M-1
363	Embedded Parts		DS	M														D1		D2									#1	H21M-1
364	Balance of Turbine Parts		DS	M																	D1		D2							H21M-1
365	Governor		DS	M										D2										D						H21M-1
366	S.C. Mandoors and Frames		DS	M										D1																H21M-1
367	Grease (Turbine)		T																		R	A				D				H21M-31
368	Oil (for Governors and Generators)		DS	M																	R	A				D				H21M-30
369																														
370	Pumps																													
371	Draft Tube Unwatering		DS	M			R	A											D											H21M-4
372	Station Drainage		DS	M			R	A											D											H21M-4
373	Dirty Lubricating Oil		DS	M				R	A											D										H21M-6
374	Clean Lubricating Oil		DS	M				R	A											D										H21M-6
375	Fire Protection and Service		DS	M				R		A											D									H21M-7
376																														
377																														
378																														
379																														
380																														
381																														
382	Air Compressors																													
383	Stationary		DS	M					R	A										D										H21M-5
384	Portable		DS	M														R	A									D		H21M-25
385	Draft Tube Evacuation		DS	M					R	A										D										H21M-5
386	Lubricating Oil Purifier																													H21M-3
387																														
388	Machine Shop Equipment																													
389	Horiz Metal Bandsaw		DS	M									R		A										D					H21M-8
390	10" Bench Lathe with Cabinet		DS	M									R		A										D					H21M-12
391	15" Sensitive Drill		DS	M									R		A										D					H21M-9
392	12" Pedestal Grinder		DS	M									R		A										D					H21M-9
393	Portable Pipe Threader		DS	M									R		A										D					H21M-10
394	Small Tools		T															R	A									D		H21M-26
395	Chain Hoists		T															R	A									D		H21M-26
396	Arbor Press (3 Ton with Pedestal)		T										R		A										D					H21M-11
397	Water Strainers		T				R		A											D										H21M-2
398	Float Cages		T					R		A										D										H21M-13
399	Oil Filters		T					R		A										D										H21M-13
400	Generator Air Cooler Flowmeters		DS	M				R		A										D										H21M-13
401	Generator Oil Cooler Flowmeters		DS	M				R		A										D										H21M-13
402	Motor-Operated Valves		DS	M				R		A										D										H21M-13
403	Proportioning Valves		DS	M				R		A										D										H21M-13, H21M-32
404	D.T. Evacuation Valves		DS	M				R		A										D										H21M-13
405	Pressure Control Switches		DS	M				R		A										D										H21M-13

Symbols: DS - Division to prepare detail drawings and specifications, except as noted under M.
T - Total handling of drawings, specifications and purchase as included under DS.
M - Division is to prepare drawings, sketches or section of specifications which is to be a part of a complete specification. This material to be supplied to the division preparing the complete specifications.
R - Issue request for requisition.
A - Award of contract.
D - Delivery.
D1 - Delivery Unit 1
D2 - Delivery Unit 2

FIGURE 351.—*Part of mechanical branch procurement schedule—Fort Patrick Henry.*

hydraulic turbines affect the design of the powerhouse substructure including the scroll case and draft tube outlines and also determine the arrangement of lifts for scheduled placement of concrete. In this respect procurement of these major items of equipment prior to making the construction, procurement and drawing schedules is highly desirable.

In the case of the Mechanical Design Branch procurement schedule another very important item requiring careful and early scheduling is piping to be embedded in concrete. Drain lines, unwatering piping, piezometers, cooling water, and other services are usually embedded in mass concrete of the initial concrete lifts. Such piping, particularly during wartime, requires several months for delivery after an award and an allowance for erection prior to concrete placement must be made.

The interval of time allowed between the requisitioning and award dates varies depending upon the type of material or equipment being requisitioned and its cost. This time allowance must provide for (1) the preparation and issue of invitations to bid by the Division of Materials (purchasing department); (2) sufficient time for the bidders to prepare and submit their proposals; (3) opening of the bids; (4) transmittal of the bids to the Division of Design branch sponsoring the procurement; (5) bid analysis by the design branch and preparation of a recommendation of award to the Division of Materials bearing the necessary approval signatures; (6) approval of the Division of Materials and any necessary approvals of the Division of Law and the TVA Board of Directors; and (7) issuance of formal award or awards to the successful bidder or bidders.

In the case of major equipment, such as hydraulic turbines, governors, etc., 2 weeks should generally be allowed for formal preparation and issue of the invitation to bid, 4 weeks for the bidders to prepare and submit their bids, 2 weeks for analysis of the bids and preparation of a recommendation of award, and 4 weeks for securing approval of the Board of Directors and issuing the formal award. The above allowances total 3 months from the requisitioning date to the award date and is the desirable timing for major equipment purchases if the exigencies of the situation will permit. Where an emergency exists this procurement time can be substantially shortened and has been in all phases of the procedure.

Procurement of smaller auxiliary items of equipment and materials such as pipe, valves, fittings, insulation, etc., can be made in a time interval of 1½ to 2 months from the requisitioning date to the award date.

The procurement schedules are squad checked through each of the design branches to ensure that the items of one branch which may affect the design and procurement work of another branch are properly scheduled from a time standpoint. In cases where procurement of certain items are the joint responsibility of two or more design branches, this is indicated on the procurement schedule by the symbols "DS" and "M." Symbol "T" indicates the total handling of procurement by one design branch which is responsible for all specifications and drawings related thereto. Symbol "DS" indicates that one design branch is responsible for the preparation

of the detailed drawings and specifications, except for a portion of the specifications and drawings which may be provided by another design branch designated by letter "M." These symbols are shown and explained in figure 351.

Illustrations of joint responsibility cases are the hydraulic turbines and governors in which the Mechanical Design Branch is responsible for preparation and issue of the basic specifications, with the Electrical Design Branch supplying portions of the specifications relating to motors, electrical instruments, and wiring. Sometimes a third design branch, such as the Civil Design Branch, may also be involved in a turbine specification to the extent that they are required to furnish general layout drawings showing the desired arrangement and dimensional limitations of the scroll case and draft tube water passages. In the case of plumbing fixtures, special drinking fountains, and toilet room accessories, the Mechanical Design Branch prepares and issues the basic specifications and the Architectural Design Branch participates to the extent of approving the style, color, and trim of the fixtures. Passenger elevator specifications are the combined efforts of the Mechanical, Electrical, and Architectural Design Branches with the Mechanical Design Branch having lead responsibility for preparation and issue.

After the procurement schedule is checked through the design branches and approved by the chiefs of the branches and the Chief Design Engineer, copies are sent to the construction project manager for his review and approval. Upon receipt of this approval copies of the schedule are distributed to all interested divisions.

Drawing schedule

The design drawing schedule is developed to meet the requirements of the construction and procurement schedules. Each of the design branch chiefs is responsible for development of a drawing schedule to cover the phase of the design work for which he is responsible. A portion of a typical Mechanical Design Branch drawing schedule, for the South Holston project, is shown in figure 352. This schedule includes drawing numbers and titles which are required for each phase of the mechanical design work for each feature of the project. For each feature the drawings required for the general arrangement of the mechanical equipment, the piping work, the plumbing facilities and the heating and ventilating, and air-conditioning systems are grouped on the schedule and numbered according to a standard numbering system. The drawing number prefix for mechanical drawings is assigned for each individual feature of a hydro project as follows:

Prefix	*Feature*
17	General, dam, spillway, intake, embankments, nonoverflow sections, tunnels, surge tank.
47	Powerhouse, control building.
67	Lock.
77	Switchyard.
87	Bridges.

Other prefixes and numbering standards have been developed for miscellaneous work (other than the main dam structures) in connection with a particular project to cover such items as warehouses, storage buildings, construction camps and villages, docks, boat

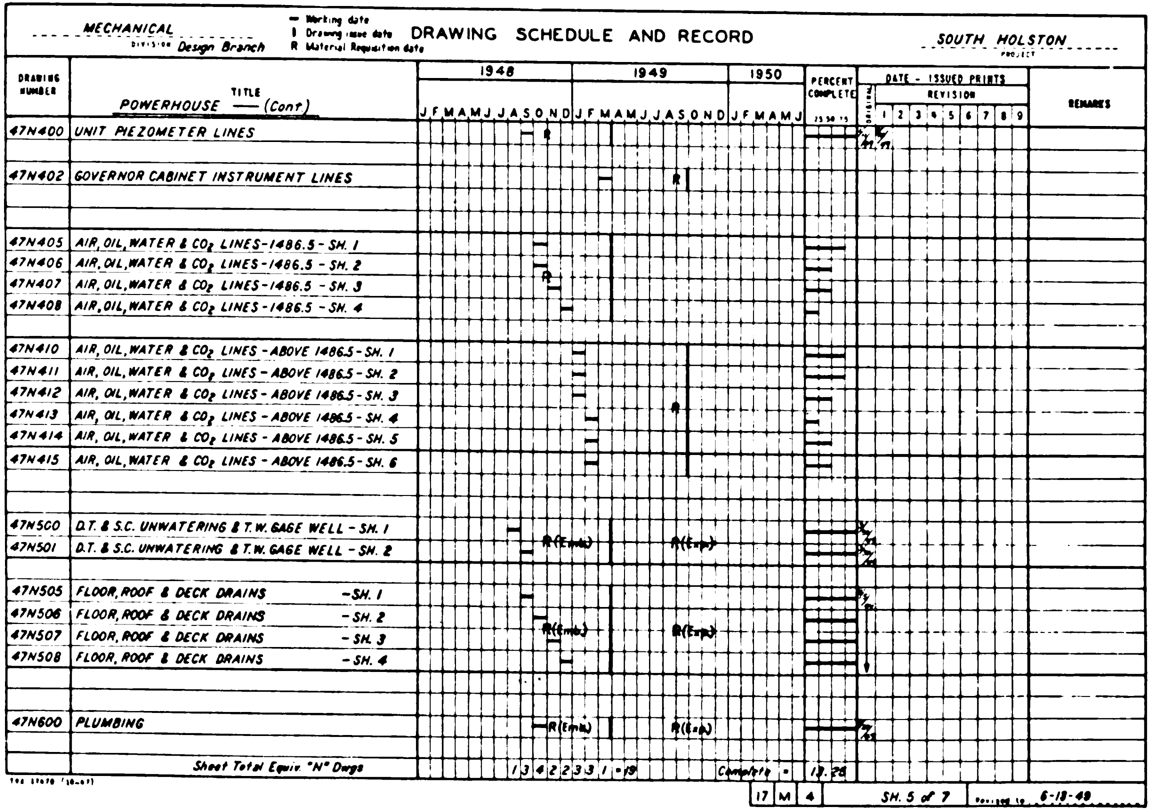

FIGURE 352.—*Part of mechanical branch drawing schedule—South Holston.*

houses, harbors, recreational developments, malaria control facilities, highway and railroad relocations, and backwater protection. Similar prefixes are assigned for the drawing numbers covering the work of the other design branches.

The letter following the feature number prefix indicates the drawing number size of which TVA has adopted several standard sizes, and the last three numbers of the complete drawing number for mechanical drawings is indicative of the type of work shown on the drawing as follows:

Drawing number series for each feature	*Type of work*
1 to 199	Studies.
200 to 299	Equipment, tanks, and piping arrangements.
300 to 399	Flow and valve operation diagrams.
400 to 499	Detailed piping services such as oil, water, compressed air, CO_2, etc.
500 to 599	Building drainage, unwatering, scroll case filling, piping.
600 to 699	Plumbing facilities.
700 to 799	Heating and ventilation.
800 to 899	Air conditioning and refrigeration.
900 to 999	Hydraulic turbines, governors, and turbine inlet valves.

The horizontal bar lines shown on the schedule opposite each drawing in figure 352 represent the working dates or the months during which the drawings must be prepared, and the vertical lines opposite each drawing represent the dates on which the drawings must be issued to the construction division. Both dates are coordinated with the construction and procurement schedules for compatibility. Working dates for any drawing or group of drawings must be carefully established to anticipate any procurement which is dependent upon completion of the design work. As an example, piping detail drawings must be sufficiently completed and a bill of material prepared to enable requisitioning of the material on the dates established on the procurement schedule. As previously indicated, in the case of piping embedded in some of the earlier scheduled concrete work, the preparation of bills of material from study drawings rather than the final detailed construction drawings may be required. Where this is necessary, the final drawing preparation dates are then scheduled at a later date but in time to permit issue in advance of their actual need for field erection purposes. Other drawings covering the details of pressure vessels, tanks, special steel fabrications and ventilating fan arrangements, grilles, dampers, and coolers which are required for procurement purposes, must be scheduled to meet the established procurement requisitioning date.

The drawing schedule also includes a column which indicates the progressive completion status of each drawing. The schedule is revised at regular intervals to reflect the drawing progress. The schedule also provides for a record of the original issue date of each drawing and all subsequent revision issue dates. Each design branch is responsible for keeping this record for its own drawing schedule.

Drawing schedules, like procurement schedules, are squad checked through each design branch to ensure consistency of the work of each branch. After this review, copies of the drawing schedules are sent to the field construction forces.

The three basic schedules described illustrate the operation and execution of the design, procurement and construction work, and their relationship. A basic system must be followed in administering and carrying out work of the magnitude of a TVA hydroelectric project; this is particularly true when the work of several projects is being carried on simultaneously.

PROGRESS REPORTS

Construction reports

The Project Manager of each project prepares brief daily and weekly reports and more detailed monthly reports covering the construction progress for submission to the Chief Engineer, the Division of Design, and other interested parties. These reports collectively include daily weather conditions, number of construction personnel on the job, location and amounts of concrete placed in each individual feature, amount of excavation and fill work done, status of turbine and generator erection, and current progress concerning erection of auxiliary mechanical and electrical equipment, structural steel, building materials, electrical conduit and wiring, and the piping systems. In reviewing these reports the design branches are kept currently informed as to the status of completion of the work insofar as it is of interest in connection with the design schedules. On a major hydroelectric project, the Civil Design Branch keeps a current record of the amounts of concrete, earth and rock fill placed. This is accomplished on prints of their general outline drawings of each feature by coloring in the various lifts shown on the drawings and the recording of the date placements are made. This information is particularly useful to the other design branches involved in detailing and procuring embedded materials.

Progress photographs are made monthly at each project to indicate visually the status of construction. Prints of current photographs are assembled in books covering all projects and are circulated regularly through the design branches.

The Office of the Chief Engineer prepares and circulates for all engineering employees copies of a monthly bulletin which summarizes the construction progress on all projects. This bulletin reports other significant items such as rainfall and runoff, important conferences and trips, personnel actions, and plans for future work. It is accompanied by a reproduction of selected construction progress photographs.

Procurement status reports

Each design branch is responsible for issuing requisitions in accordance with the dates shown on the procurement schedule. In the Mechanical Design Branch the responsibility for meeting this schedule is divided among the several section heads who act as sponsor engineers in preparation of procurement requisitions and specifications. Overall day-to-day review of all procurement schedules is made by the head of the Mechanical Design Branch procurement section through which all requisitions are forwarded.

Where many projects are being designed simultaneously the importance of making frequent schedule reviews cannot be over-stressed.

It is the general practice in the Mechanical Design Branch to prepare a procurement status report every 3 months and to provide each sponsoring engineer who is responsible for procurement or work related thereto with a copy. These reports include all projects and list any delinquent procurements which have not been made on the date of issue of the report as well as each individual procurement to be made in the forthcoming 3-month period. A portion of a typical periodic procurement status report is shown in figure 353. The scheduled requisitioning date taken from the formal procurement schedule, the responsible sponsor engineer, and any pertinent remarks opposite each item are shown. The breaking down of procurements which are to be made in a 3-month period is a convenient means of summarizing and reminding sponsor engineers of

February 1, 1954

MECHANICAL DESIGN BRANCH
PROCUREMENT REQUISITIONS

Due through 5-1-54 (Except as Noted)

Project and Description	Schedule Reqn Date	Sponsor	Remarks
Chatuge (Complete)			
Valve Marker Tags	2-1-54	CWB	
Turbine Grease	2-15-54	CLN	
Turbine, Governor and Generator Oil	2-15-54	CLN	
Nottely (Complete)			
Steel Tanks	1-1-54	CWB	
Special Valves - Meters, Etc.	2-1-54	CWB	
Plumbing Fixtures	2-1-54	CWB	
PH - Embedded Piping	2-1-54	CWB	
Well Water Supply Pump	3-15-54	CWB)	Hear Broadfoot
Chlorinator	3-15-54	CWB)	Cannot Delay
T.W. Supply Piping	3-15-54	CWB)	
Yard - Sanitary Waste Facilities	4-15-54	CWB	
Intake - Sluice Gate Oil Piping	4-15-54	CWB	
S.Y. - Oil Piping & Hose	5-1-54	CWB	
PH - Exposed Piping & Spec	5-1-54	CWB	
PH - H & V Eqpt	5-1-54	BSM	
PH - Pipe Insulation	8-1-54	CWB	
PH - Turbine Grease	1-1-55	CLN	
PH - Oil for Gov & Generator	1-1-55	CLN	
Valve Marker Tags	1-1-55	CWB	
Hiwassee Unit 2 (Complete)			
PH - Emb Piping	1-1-54	CWB	
PH - H & V Equipment	6-1-54	BSM	
PH - Exp Piping & Spec	7-1-54	CWB	
S.Y. - Oil & Air Piping	7-15-54	CWB	
PH - Pipe Insulation	8-1-54	CWB	
PH - Hatch Cover Insulation	8-1-54	BSM	
Valve Marker Tags	11-1-54	CWB	
PH - Turbine Grease	1-1-55	CLN	
PH - Oil for Gov & Generator	1-1-55	CLN	

FIGURE 353.—*Part of typical periodic procurement status report.*

the work on which they should concentrate from the procurement standpoint. This is particularly true since the formal procurement schedule of a project consists of many sheets and the requisitioning sometimes extends over a period of 2 to 3 years. The somewhat laborious process of reviewing the formal procurement schedules is multiplied by the number of projects being handled and the short form procurement status report reduces the amount of time which each sponsor engineer must devote to such reviews.

The office of the project manager at the construction projects prepares procurement status reports and submits them to the Chief Design Engineer for review of any delinquent items and for comments concerning the rescheduling of requisition and delivery dates.

BOONE HYDRO PROJECT AUGUST 1, 1952

STATUS OF MECHANICAL BRANCH DRAWINGS

Sheet No. 1

Dwg. No.	Title	Percent Complete Last Report	This Report	Gain	Remarks
17N200	Yd - Water & Sewer Lines Sh 1	25	75	50	
17N201	Yd - Water & Sewer Lines Sh 2	0	50	50	
17N405	Intake - Misc Piping Sh 1	25	75	50	
17N406	Intake - Misc Piping Sh 2	0	50	50	
47N200	PH - Units 1-3 - Gen Arrgt Sh 1	50	100	50	
47N201	PH - Units 1-3 - Gen Arrgt Sh 2	25	75	50	
47N300	Valve Diag - Misc Systems Sh 1	50	100	50	
47N301	Valve Diag - Gov & Lub Oil Sys Sh 2	25	75	50	
47N302	Valve Diag - Unwatering Sys Sh 3	0	25	25	
47N410	SB - Air, Oil, & Water Lines Sh 1	50	75	25	
47N411	SB - Air, Oil, & Water Lines Sh 2	25	75	50	
47N701	PH - Heating & Vent Plans Sh 1	50	100	50	
47N702	PH - Heating & Vent Plans Sh 2	25	75	50	
47N550	CB - Drains & Service Lines Sh 1	50	100	50	
47N555	CB - Water-Treat. Plant Sh 1	50	100	50	
47N556	CB - Water-Treat. Plant Sh 2	25	75	50	
47N650	CB - Plumbing	25	75	50	
47N801	CB - Heat, Vent, & A-C Plans Sh 1	50	100	50	
47N802	CB - Heat, Vent, & A-C Plans Sh 2	25	75	50	
47N803	CB - Heat, Vent, & A-C Plans Sh 3	0	50	50	
77N201	Swyd - Oil & Water Lines Sh 1	50	100	50	
77N202	Swyd - Oil & Water Lines Sh 2	25	75	50	
			TOTAL	10.50	

TVA 2301 (DES-5-49)

FIGURE 354.—*Typical monthly squad drawing report.*

Design drawing reports

Each design branch prepares a monthly report to the Chief Design Engineer indicating the percentage of completion of the design work for each individual project. The responsibility for the preparation of this monthly report in the Mechanical Design Branch is that of the branch production engineer working in collaboration with individual squad supervisors and the section head engineers. The development of the monthly report is as follows:

1. Each squad supervisor prepares a drawing status report covering the type of work for which he is responsible for each individual project. On a hydroelectric project separate drawing reports are prepared by the piping squad, plumbing squad, water- and sewage-treatment plant squad, heating, ventilating and air-conditioning squad, and the turbine design section. These reports are prepared on drawing status forms as shown in figure 354. Each project drawing report lists all drawings actively under design, including the drawing number, title, percent complete of each drawing as claimed on the last monthly report, percent complete on present report, and the equivalent percentage gain. The total gain in design progress for a particular project is usually expressed by the total number of drawings completed during the month which is summarized at the bottom of the report. These individual reports are submitted through the section head engineers at the end of each month to the branch production engineer.
2. The branch production engineer plots the progress reported on the drawing reports on each individual drawing schedule in the percentage completion column (fig. 352). When all squad reports for a particular project are plotted he prepares a drawing status report summarizing the progress of the Mechanical Design Branch for that project. Figure 355 illustrates a project drawing status report for the Mechanical Design Branch. This report indicates the total number of mechanical drawings scheduled, the total number of drawings completed and the percent of design work completed for each individual project feature. This report summarizes the total work for all features at the bottom and indicates the amount of design drawing gain over the preceding monthly report.
3. The production engineer then prepares a single sheet report which summarizes the monthly gain for all active projects. This report summary sheet is shown in figure 356.

The squad drawing reports under 1 (above), which are to enable the production engineer to summarize the progress for each individual project, are retained in the design branch files. Copies of the project reports and the summary report indicated under 2 and 3 (above) are forwarded to the Administrative Services Section of the Chief Design Engineer's office who, together with the Administrative Assistant to the Chief Design Engineer, are responsible for preparation and submission of the monthly report to the Chief Engineer covering the activities of the work of the overall Division of Design.

The Mechanical Design Branch has found it advantageous to maintain a graphic record of design drawing progress for each individual project. Figure 357 illustrates a typical drawing progress chart for the mechanical work in connection with the Fort Patrick Henry project. The solid black line on the chart represents an accumulative plotting of the number of drawings set forth on the drawing schedule according to the monthly working dates established over the design period for the project. The dashed line paralleling the scheduled progress line represents the accumulative actual drawing progress accomplished. This graphic record shows at a glance the design drawing status and serves as a challenge to the designers to stay "ahead of the game."

TVA 2337 (DES-3-53)

MECHANICAL DESIGN BRANCH
MONTHLY RECORD OF STATUS OF DRAWINGS
June 1, 19 49 WATAUGA HYDRO PROJECT

Feature	Final Dwgs. Required	Equivalent "F" Dwgs. Scheduled	Equivalent "F" Dwgs. Complete	Percent Complete
17 GENERAL				
Dam	3	3.0	3.0	100
Embankments & Yard	5	5.0	4.5	90
Intake) Power Tunnel)	3	3.0	3.0	100
Spillway	7	7.0	7.0	100
Visitors Facilities	5	5.0	3.0	60
TOTAL	23	23.0	20.5	89.1
47 POWERHOUSE & SERVICE BAY				
Piping	38	38.0	35.0	92
Heating & Ventilating & A.C.	15	15.0	12.5	83
Turbines	9	6.1	4.0	66
TOTAL	62	59.1	51.5	87.1
47 CONTROL BUILDING				
Piping	5	5.0	4.0	80
Heating & Ventilating & A.C.	20	20.0	18.7	94
TOTAL	25	25.0	22.7	90.8
67 LOCK				
Piping				
Heating & Ventilating & A.C.				
TOTAL				
77 SWITCHYARD	4	4.0	3.5	87.5
87 BRIDGES	1	1.2	1.2	100
107 MISCELLANEOUS				
Camp & Village	14	14.0	14.0	100
Maintenance Building	1	1.0	1.0	100
Revised Drawings				
TOTAL THIS REPORT	130	127.3	114.4	89.9
TOTAL LAST REPORT	130	127.3	110.2	86.6

NOTES: Gain 4.2

FIGURE 355.—*Typical monthly project drawing report.*

Inspection reports

The Inspection and Testing Branch of the Division of Design, upon specific request of the design branches and other TVA divisions, makes engineering inspections and witnesses tests of equipment and materials during the manufacture and fabrication of such items at the manufacturing plant. Field inspectors are located at various manufacturing plants or in certain manufacturing areas throughout the country. Periodic inspection reports covering the progress of manufacture of a particular item of equipment or material are submitted by the field inspectors to the Head Materials Engineer who in turn distributes copies of the reports to all divisions concerned. A typical inspection report is shown in figure 358.

TVA 5151 (DES-3-52)

MECHANICAL DESIGN BRANCH
SUMMARY OF DRAWING PROGRESS
MONTH OF June 19 52

PROJECT	Equiv. "N" Dwgs.Comp. During Mo.	Percent Complete
Widows Creek Steam Plant - Units 1-4	1.5	99.5
Widows Creek Steam Plant - Units 1-4 Rev for 5 and 6	2.0	79.5
Widows Creek Steam Plant - Units 5 and 6	16.5	63.5
Kingston Steam Plant - Units 1-4	45.4	76.5
Kingston Steam Plant - Units 5 and 6	2.6	—
Shawnee Steam Plant - Units 1-4	11.7	94.6
Colbert Steam Plant - Units 1-4	19.2	12.0
Boone Hydro Plant	2.7	88.2
Fort Patrick Henry Hydro Plant	5.3	62.7
Power Service Building (Wilson Reservation)	1.2	76.3
Douglas Hydro Plant Unit 4	2.0	59.4
Wheeler Hydro Plant Switchyard	.2	66.6
* Watauga Hydro Plant (Flowmeters)	.2	100.0
Cherokee Hydro Plant Unit 3	.0	90.4
Cherokee Hydro Plant Unit 4	.0	91.0
Fontana Hydro Plant Unit 3	.0	88.1
Hales Bar Hydro Plant Units 15 and 16	.0	94.6
Wilbur Hydro Plant Turbine Curves	.0	77.8
TOTAL	110.5	

*PROJECT COMPLETED

[illegible] Engr.
Production Engineer

FIGURE 356.—*Typical monthly drawing progress summary—all projects.*

The inspector is responsible for determining the quality and accuracy of the manufacturer's work, conformance of the work to the detailed specifications, and the witnessing of any specified tests performed by the contractor at his plant. He forwards copies of such tests to the responsible design branch for approval and upon completion of the contractor's work authorizes release for shipment to the job site. Such work involves the securing of copies of all of the contractor's material orders to various suppliers and frequently occasions visits to the plants of subcontractors. In addition he performs an expediting service toward securing delivery of the equipment within the specified time.

498128 O—60——48

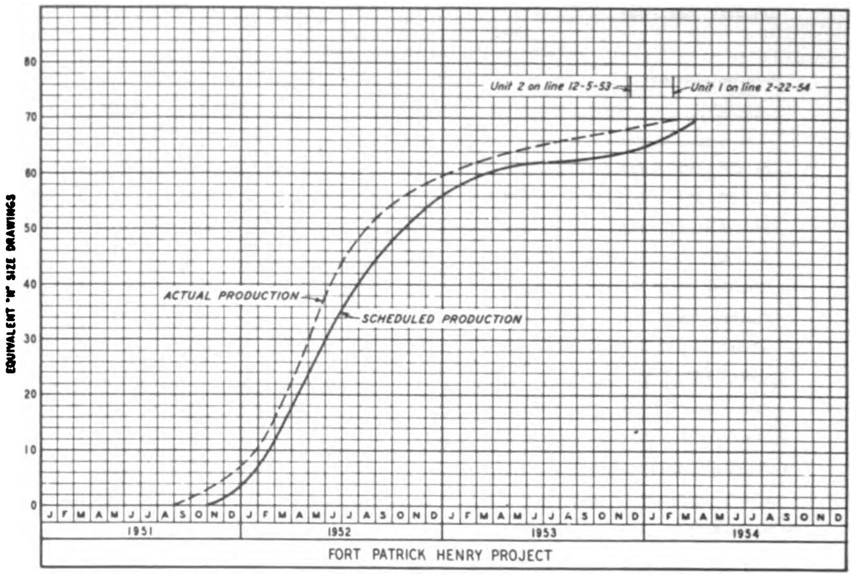

FIGURE 357.—*Mechanical design drawing progress chart—Fort Patrick Henry.*

Other design reports

As previously stated the Chief Design Engineer submits a monthly report to the Chief Engineer covering the design progress on each active project. In addition to actual design drawing progress this report includes any significant decisions made during the month effecting changes or additions to the design work load, records important conferences with other divisions, lists major procurement actions, reports on personnel turnover and recruitment, and in a general way covers all activities of the division.

Similarly, the Office of the Chief Design Engineer submits an annual report to the Chief Engineer covering all activities and progress during the fiscal year. This report is an assemblage of annual progress reports submitted by the individual design branches and, in addition to design progress, includes data concerning new engineering design developments and the reporting of work improvement ideas. This Division of Design report provides some basic information for the Chief Engineer's annual report and, in turn, part of the essential data for the overall TVA annual report to Congress.

At the completion of a major project the Division of Design prepares a final design report setting forth all phases of the design work, including a description of each feature of the project, a discussion of alternate designs considered, special studies and model tests performed, and a complete statistical summary of all installed equipment and systems. Each design branch is responsible for preparing its portion of the final design report.

PROCUREMENT PROCEDURE

Requisitions

For purchases sponsored by the Division of Design, requisitions and any necessary specifications, order lists, drawings, and other

TVA 1140A (OES-11-48)

TENNESSEE VALLEY AUTHORITY
INSPECTION AND TESTING BRANCH
INSPECTION REPORT

CONTRACT 31/C-53-18861 REQ. 31/678301

DESCRIPTION Hydraulic Pump Turbine

CONTRACTOR Allis-Chalmers Mfg Co., West Allis, Wisconsin. REPORT NO. 6

PROJECT Hiwassee Dam Unit 2 DATE 6-4-54

SHEET 1

CONTRACT SHIPPING DATE TURBINE: February 1, 1955.

CONTRACTOR'S PROMISE Turbine: February 1, 1955.

INSPECTOR'S ESTIMATE No estimate at this time.

At contractor's plant good progress is being made on the fabrication of the Spiral Case.

Forming of the plates is complete on Sections 3 - 4 & 5

Forming of the plates is in progress on Sections 1 & 2

Assembling of Scroll Case to Stay Ring Section #5 complete.

Welding of scroll case to stay ring section #5 — 70% complete.

Assembly of Scroll Case to Stay Ring Section #4 complete.

Welding of Scroll Case to Stay Ring Section #4 — 20% complete.

Assembling of Scroll Case to Stay Ring Section #3 will start 6-8-54.

Balance of the sections will follow back to Section #1.

Layout on plates for Draft Tube Liner and Discharge Ring is under way.

Workmanship is good and progress is satisfactory at this time.

This is a partial report.

L. T. Matthews, Inspector

DISTRIBUTION:
CHIEF, MATERIALS BRANCH

J. G. Quinley - Chattanooga	H. J. Petersen - 204 UB
Paul Fahey - Chattanooga	H. F. Corden - Chattanooga
R. A. Monroe - 305 UB	(2) H. L. Broadfoot - Murphy, N. C.
G. K. Leonard - 607 UB	(2) C. L. Karr - Chattanooga

FIGURE 358.—*Typical inspection report of inspection and testing branch.*

accompanying papers are prepared by the appropriate design branch. Requisitions are prepared on a standard form (TVA 201) and sufficient copies of the requisition and all accompanying papers are reproduced to permit distribution as hereinafter indicated. A typical requisition is shown in figure 359. Signatures on requisitions are as follows:

Initiated by—Sponsor Engineer
Requested by—Chief of Branch
Authorized by—Chief Design Engineer
Validated by—Office of the Chief Engineer

The sponsor engineer is responsible for preparation of the specifications relating to the procurement, the establishment of scheduled

TVA 201 (Mat-4-48)

TENNESSEE VALLEY AUTHORITY

Purchase Requisition

PERMANENT MATERIAL
Design Ref H21M-4
Req. No. 50232

Location Knoxville, Tennessee   Date January 25, 1952

Project Fort Patrick Henry
Organization Construction (by Mechanical Design)
Acctg. Office Upper Holston
Budget No. H21-39   Acct. No.

Ship To Tennessee Valley Authority
Attention of Chief Storekeeper
Johnson City, Tennessee
Boone Dam for Fort Patrick Henry
Via Best way   Date Wanted Feb. 1, 1953

ITEM CLASS No.	ARTICLES OR SERVICES Give Complete Description or Catalog Number	QUANTITY	UNIT	ESTIMATED UNIT PRICE	ESTIMATED AMOUNT
	VERTICAL, TURBINE-TYPE PUMPING UNITS FOR DRAFT TUBE UNWATERING AND STATION DRAINAGE FOR FORT PATRICK HENRY PROJECT				
	Furnish, sell, and deliver the above equipment in accordance with the attached specification No. 4735. Early procurement is recommended to obtain design data.				
	Estimated cost - Not to exceed		Lump Sum		$8500
	Procurement items 371 and 372				
	Inspection - Destination				
	Bids to be reviewed by Division of Design before award.				
	Initiated by C. W. Bolieau				

VERIFICATION CLAUSE — The articles enumerated hereon are not available in stock and upon investigation it was found that they could not be procured from any other branch of the Government without transfer of funds, or the immediate need for these supplies or the remoteness of shipping points of supply preclude their purchase from any other branch of the Government

Requisition Clerk

Requested by Head Mechanical Engineer   Validated by Budget Supervisor

Authorized by R. A. Monroe, Chief Design Engineer   Title   Approved   Materials Branch

FIGURE 359.—*Typical purchase requisition.*

delivery dates, development of the estimated cost of the equipment or materials and formulation of any special clauses of the conditions of bid concerning data to be submitted by bidders, bid evaluation, and bidder's qualifying experience. He includes with the requisition a list of vendors who may be interested in bidding on the requirement. If the project carries a defense priority rating, the requisition must include any data necessary to conform to priority regulations such as estimated weights of any controlled materials and quarterly delivery requirements.

In the Mechanical Design Branch, all specifications are routed through the branch procurement section which prepares or reviews the actual requisition and is responsible for scheduling, recording, reporting, expediting, and maintaining all contract procurement

documents and correspondence. Major equipment specifications such as hydraulic turbines, governors, large turbine inlet valves, and auxiliary equipment specifications such as pumps, air compressors, heating, ventilating, air-conditioning equipment, and water and sewage-treatment plant equipment and plumbing fixtures are generally prepared by the section's head engineers or their assistants. Specifications covering other items such as machine shop equipment, auxiliary power generators, passenger elevators, oil purification equipment, and pipe, valves, fittings, and accessory materials are generally prepared by the head engineer of the procurement section. Typical specifications for mechanical equipment are included in appendixes A, B, and C.

After requisitions and accompanying papers are prepared and reproduced they are forwarded to the office of the Contracts Engineer in the Inspection and Testing Branch, who is responsible for reviewing all procurement documents for conformity with established standards and for issuing requisitions and receiving and distributing copies of invitations to bid, bids, and contract documents to the design branches. When the requisition is for a major or special item of equipment which definitely would not be available as surplus or excess equipment at any of the TVA projects, the Contracts Engineer forwards the requisition including the specifications and drawings (if required) together with the duplimat masters, direct to the Division of Materials for handling the procurement. At the same time, distribution of copies is made to the sponsoring design branch, other interested design branches, the Chief Design Engineer, the Chief Construction Engineer, and the Project Manager.

On requisitions covering other items of material, such as pipe, valves, fittings, lead, jute, and insulating materials, the sponsor engineer indicates by notation on the requisition that a check of the excess materials stocks should be made prior to actual purchase of the specified materials. In such cases the Contracts Engineer distributes copies of the requisition as previously indicated except that the duplimat masters and copies which are to be sent eventually to the Division of Materials are routed through the Chief of the Construction Plant Branch. This branch is responsible for coordinating the requisition with the project construction branch for which the materials are being ordered to ascertain if any of the requested materials are available in surplus or excess materials stocks at that project or at any other TVA project. Items found in stock are transferred to the project requiring the materials and the quantities of such materials indicated on the requisition are reduced by that amount. All questions concerning the acceptability of items of excess or surplus materials are directed to the sponsor engineer of the requisition. After this check of available stocks is made the revised requisition in forwarded to the Division of Materials for procurement of the remaining materials. This procedure has been quite beneficial in materially reducing TVA surplus stocks and thereby promoting overall project economy.

Invitations to bid

The Division of Materials is responsible for preparing and issuing invitations to bid (or negotiating the transaction), opening the bids received, transmitting the bids to the sponsoring design branch for

analysis and recommendation of award, reviewing recommendations of award, securing any necessary board approvals on recommendations for award, and awarding the contracts. The actual functioning of the Division of Materials in carrying out its work will not be covered herein except in a general way and as it relates to the operation of the Division of Design.

The General Procurement Branch of the Division of Materials buys all materials except coal and coke. It contains four purchase sections: electrical, mechanical, structural, and field. The field section consists of purchasing agents stationed at various locations who handle requisitions issued by the construction division and other organizations at these locations. When a requisition is received in the branch, it is assigned to an appropriate purchasing agent. Except in the electrical section, which has an expediter who expedites all that section's contracts, one purchasing agent handles the procurement transaction from receipt of the requisition to acceptance of the material at the job site and authorization for payment. Coal and coke are bought by the Coal Procurement Branch.

The time allowances for issuing the invitation to bid after receipt of a requisition, for submission of bids, bid analysis, preparing the recommendations for award, and making the award are covered in this chapter under the subject of procurement schedules. A typical invitation, bid, and acceptance form and bid schedules are shown in appendix A, starting on page 745. After all bids are received and opened at the Division of Materials offices, the purchasing agent forwards the bids to the sponsoring design branch for analysis and preparation of a recommendation of award. In some cases, the bids are accompanied by an abstract of the bids prepared by the Division of Materials. Such abstracts include a listing of the prices of all bidders, delivery dates, discounts offered, acceptance dates, and notations concerning any exceptions taken by the bidders to the TVA specifications and conditions of bid. Abstracts are seldom necessary for equipment purchases but may serve a useful purpose in the procurement of multiple items of materials such as pipe, valves, fittings, and accessories.

Bid analyses and recommendations of award

In the Mechanical Design Branch, a tabulation of the bids is prepared by the head of the procurement section or the sponsor engineer. Bid tabulations include the bid number, bidders' names, bid price, and promised shipping time and in some cases other pertinent data such as erection time, discounts, and acceptance dates. The order of listing bids is determined by price magnitude with the price of the lowest bidder being entered first. Where several schedules are involved such as on pipe, valve, and fitting purchases, separate tabulations are made of the bids received for each schedule in numerical schedule order. Typical bid tabulations with recommendation of award are shown in figures 360 and 361.

The sponsor engineer is responsible for reviewing and analyzing the bids and completion of the preparation of the recommendation of award. This involves examining the bid of the lowest bidder first and all higher bidders in succession to determine (1) conformity with the technical requirements of the specifications; (2) meeting of specified delivery times; (3) bidders' qualifications concerning

special experience clauses; and (4) evaluation of any other factors which affect the over-all cost of the equipment or material to TVA. Bids, involving unit prices based on estimated quantities in which the final cost will be determined on actual quantities or amounts of work done or materials furnished, are carefully examined to determine if any unbalance exists. Most invitations to bid on major

February 28, 1952

F. A. Lowe, Purchasing Agent, Materials Division, Chattanooga

H. J. Petersen, Head Mechanical Engineer, Design Division, Knoxville

RECOMMENDATION OF AWARD OF CONTRACT FOR INSULATING AND LUBRICATING OIL PURIFIERS FOR FORT PATRICK HENRY HYDRO PLANT - REQUISITION NO. 658925

We have analyzed the bids received on the above subject and tabulate below the cost f.o.b. destination:

Bid No.	Bidder	Cost	Shipment (Days)
	(Items 1 and 2)		
1	A	$13,037.00	240
2	B	16,330.00	180 - 210

The low bidder meets the specifications in all respects and offers a shipping time meeting our stated delivery requirement.

We, therefore, recommend award of contract for items 1 and 2 to Bidder No. 1, designated "A" above, for the sum of $13,037.00, discount 2% 10 days, for shipment within 240 days after notice of award of contract.

Estimated cost - $13,000
Rejection - Other bid due to higher price
Notification - Letter
Engineer - Head Mechanical Engineer
Inspection - Head Materials Engineer

Original copies of both bids are returned herewith.

R. A. Monroe
Chief Design Engineer

Head Mechanical Engineer

Chief Engineer

R. E. Gibson
Contracts Engineer

RMG:CM
Attachments
CC: P. J. Freeman (2), 102 AB
R. E. Gibson, 103 AB
C. L. Karr (2), Chattanooga
G. K. Leonard, 607 UB
F. A. Lowe, 2/original
R. A. Monroe, 305 UB
W. K. Seaman, Johnson City

FIGURE 360.—*Typical recommendation of award of contract for major item of equipment.*

May 1, 1951

M. H. Segrest, Purchasing Agent, Materials Division, Chattanooga

H. J. Petersen, Head Mechanical Engineer, Design Division, Knoxville

RECOMMENDATION OF AWARD OF CONTRACT FOR EMBEDDED PIPING MATERIALS
HIWASSEE PROJECT UNIT 2 - REQUISITION 57-50320

We have analyzed the bids received on the above subject and tabulate below the cost f.o.b. destination.

Bid No.	Bidder		Cost	Shipment (Days)
	Schedule I - Valves			
5	C	(a)	$2,834.50	30
4	D		2,900.00	60
1	E		2,975.00	42
3	F		3,130.00	Stock
2	G		3,142.00	56
	Schedule II - Fittings			
1	E	(b)	$1,863.00	150
3	F		1,870.00	60
2	G		1,943.60	45
5	C		2,050.00	75
4	D		2,261.00	30
	Schedule III - Steel and Wrought Iron Pipe			
3	F		$3,365.00	Stock
1	E	(c)	3,388.00	42
2	G		3,523.00	45

(a) Reject - Bidder has failed to bid on items 5 and 9. His bid is, therefore, incomplete.

(b) Reject - Bidder's time of delivery exceeds our requirement of August 1, 1951.

(c) This bidder is low by discount.

We recommend award of contracts as follows:

Schedule No.	Bid No.	Bidder	Cost	Discount	Shipment (Days)
I	4	D	$2,900.00	2% 10 days	60
II	3	F	1,870.00	1% 30 days	60
III	1	E	3,388.00	2% 30 days	42
			$8,158.00		

Estimated cost - $8,500
Rejection - All other bids due to higher prices
or for reasons stated
Notification - Letter
Engineer - Head Mechanical Engineer
Inspection - At destination

Original copies of all bids with abstract are returned herewith.

R. A. Monroe
Chief Design Engineer

H. J. Petersen
Head Mechanical Engineer

R. E. Gibson
Contracts Engineer

RMG:CM
Attachments
CC: H. L. Broadfoot (2), Murphy
R. E. Gibson, 503 AB
R. A. Monroe, 305 UB
H. J. Petersen, 204 UB
M. H. Segrest, 2/original

FIGURE 361.—*Typical recommendation of award of contract for piping materials.*

equipment include in the special conditions a clause concerning bidders' experience and facilities and evaluation of bids. These experience clauses are now tailored to the individual requisition in most cases, and are cleared with the Division of Law before use. However, a typical clause used in the invitations to bid on major equipment for the plants described in this report is quoted as follows:

> *Experience, facilities, and evaluation of bids.*—Bidders may be required to furnish upon request evidence satisfactory to TVA that they have financial resources, business and technical organization, and working capital to begin the work promptly and prosecute it vigorously in such manner as to secure completion within the time specified.
>
> Because of the extreme importance of having skilled workmanship for this installation, TVA reserves the right to reject all bids from bidders which, in its opinion, are not fully qualified to do the work. No award will be made until TVA is satisfied, by personal inspection if necessary, that the prospective Contractor has adequate personnel and technical facilities, and uses the most modern and approved method to produce a first-class job. These factors will be evaluated in comparing bids.
>
> In comparing bids and in making award TVA may consider such factors as relative quality and adaptability of supplies or services, the bidder's financial responsibility, skill, experience, record of integrity in dealing, ability to furnish repairs and maintenance services, the time of delivery, performance offered, and whether the bidder has complied with the conditions of bid and with the pertinent requirements of the specifications.
>
> Whenever applicable, equalizing elements or factors not specifically mentioned or provided for herein, such as the cost of transportation, erection, construction or inspection (including salaries, travel, and subsistence expenses), or any other element or factor in addition to that of the bid price which would affect the final cost to TVA may be taken into consideration in making award of contract.

In comparing bids and preparing a recommendation of award the sponsor engineer takes the above factors into consideration.

Footnotes referenced opposite each bidder's name in the tabulation are usually employed on a recommendation of award to explain any deviations from the bid requirements and reasons for rejecting a bid due to technical violation of the specifications.

At the end of the bid analysis, the recommendation of award to a particular bidder or bidders is given together with a statement concerning the amount of the award, discounts if any, and promised shipping time. A statement concerning concurrence of other divisions such as the Division of Power Operations or the Division of Construction with the recommendation of award is sometimes indicated. The recommendation of award is generally concluded with references to the original requisition estimated cost, designation of the head technical engineer and assignment of whether the inspection is to be made by the project construction forces upon receipt of the equipment at the job site or by the Head Materials Engineer who is responsible for inspection and testing of equipment at the contractor's plant. In addition the recommendation may include a suggestion as to the method the purchasing agent should employ in notifying the successful bidder of award of contract; that is, either by letter, telegram, or telephone. The usual notice of award is the contract itself. If time is short, the purchasing agent would wire or phone notice of award whether or not the recommendation requests it.

Recommendations for award of contracts prepared by the Division of Design for purchases totaling $10,000 or more are approved and signed by the Head Technical Engineer, the Contracts Engineer, the

Chief Design Engineer, and the Chief Engineer. Recommendations for award of contracts for purchases totaling $5,000 or more but less than $10,000 include the signatures of the Head Technical Engineer, the Contracts Engineer, and the Chief Design Engineer. Recommendations for award of contracts for purchases totaling less than $5,000 are signed only by the Head Technical Engineer and the Contracts Engineer. The above procedure applies in all cases where awards are being recommended to the lowest bidders meeting the specifications. Where recommendation is made for award to other than the low bidder meeting specifications, the signatures of all four engineers are required.

Upon completion of the bid analysis and the recommendation of award, these documents and all bids are sent to the purchasing agent through the office of the Contracts Engineer. Copies of the recommendation of award are distributed to all interested TVA offices.

Contract awards

The purchasing agent reviews the recommendation for award and examines the bids for compliance with all contract terms. If he concurs with the recommendation, he secures the necessary approvals and makes formal contract awards to the successful bidders. All awards of $50,000 or more require the approval of the TVA Board of Directors; also, certain other awards to other than the low bidder require Board approval. The purchasing agent provides copies of notices of award, contract documents, and related correspondence to all interested divisions.

After award of contract the purchasing agent becomes the contract enforcement officer for TVA in authorizing such items as price changes, assisting in expediting deliveries, issuing delivery status reports, and administering all terms of the contract. His work does not include the handling of the technical details and approval of the manufacturers drawings of the equipment as this is the responsibility of the head technical engineer of the sponsoring design branch. The Head Technical Engineer and the purchasing agent must work in close relationship to ensure that all phases and terms of the contract are met and successfully carried out.

CONSTRUCTION SPECIFICATIONS

The Division of Design prepares and issues to the construction division any separate construction or erection specifications which it considers necessary to the building of a structure or the installation of the equipment to ensure proper design functioning. The Mechanical Design Branch in this connection with regard to the design of hydroelectric developments usually issues the following construction and erection specifications:

1. Field Erection Specification for Hydraulic Turbines, Alignment of Turbine and Generator Shafts, and Final Tests of Turbines and Governors.
2. Construction Specification for Applying Insulation to Air-Conditioning Ducts, Equipment, and Generator Hatch Covers.
3. Construction Specification for Applying Insulation to Miscellaneous Piping Systems.
4. Construction Specification for Disinfection of Water Pipe Systems.

The above specifications, with the exception of the latter specification which is a general standard specification, are prepared sep-

arately for each individual project. Copies of typical construction specifications of this nature are included in appendixes A and D. In general the design drawings include notes covering any instructions relating to construction and the preparation of special construction specifications similar to those listed above are not required.

OPERATING INSTRUCTIONS

The Division of Design in connection with its work on a major hydroelectric development prepares and issues to the Division of Power Operations and the Division of Construction any special operating instructions which it considers necessary to successful operation of the power plant equipment and auxiliary piping systems. In the Mechanical Design Branch such instructions are generally confined to the following items:

1. Operating Instructions for the Oil Systems and Oil Handling Equipment.
2. Operating Instructions for the Powerhouse Draft Tube Unwatering, Scroll Case Filling, and Station Drainage Systems.
3. Operating Instructions for the Water-Treatment Plant.
4. Operating Instructions for the Powerhouse Raw Water Systems.
5. Operating Instructions for the Heating, Ventilating, and Air-Conditioning Systems.

In addition to the above, copies of all manufacturers' equipment operating instructions are provided to construction and operating personnel. Copies of some of the typical operating instructions prepared by the Mechanical Design Branch are included in appendix E.

DESIGN PRODUCTON COSTS

The Budget and Cost Control Unit of the Administration Services Section of the Division of Design is responsible for keeping and compiling of all records in connection with the production costs of the design work. In determining these costs for a project the time spent by all Division of Design personnel engaged on that particular project is compiled. These time charges include those of the design branch chiefs, the engineers, designers, checkers, draftsmen, tracers, secretaries, and clerks and in addition general expenses covering charges of the staff, typing, blueprinting, reproduction, travel, consulting services, etc. The charges for work performed by the Inspection and Testing Branch in connection with factory equipment inspection is not included in the design cost but is included in the construction cost.

The Budget and Cost Control Unit prepares and issues monthly reports for each project showing the amount of money spent by each design branch during the month and the total amount spent on the project to date. These reports include the charges for general design expense and also indicate the percentage complete of the design work of each design branch and that of the overall division.

Similar monthly reports for each project are compiled and issued covering the amounts spent on the preparation of "as constructed" record drawings which show the actual installed work including all field changes. Monthly reports are also issued for each project covering the charges for preparation of final design reports.

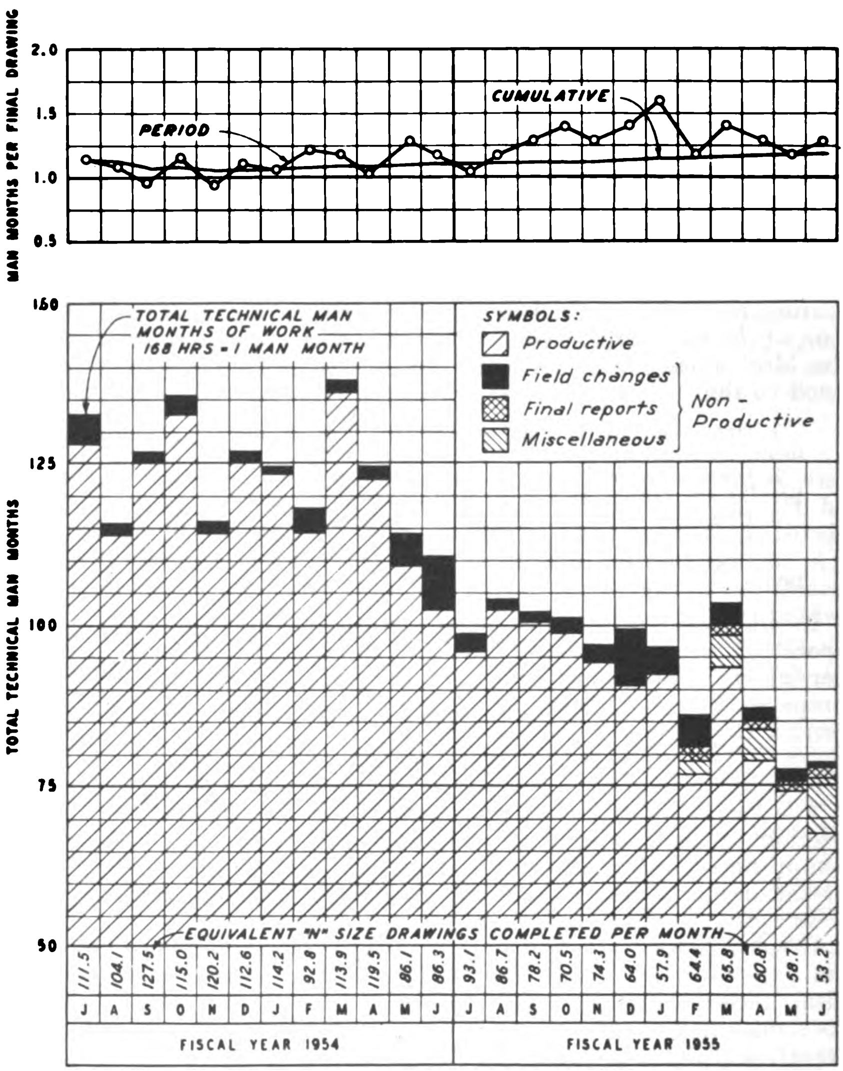

FIGURE 362.—*Mechanical Design Branch drawing production data chart.*

Design production data charts are prepared for each design branch and the overall Division of Design. These charts are plotted and issued monthly by the Budget and Cost Control Unit. A typical production data chart for the Mechanical Design Branch is shown in figure 362. This chart presents a monthly and cumulative record of the total number of drawings produced for all projects, the average number of man-months required to produce each drawing, the total technical personnel engaged in producing the work, and a breakdown of the number engaged in the performance of productive and nonproductive work. The number of drawings produced is taken directly from the mechanical design drawing monthly status reports

and the technical personnel engaged in the work is taken directly from the individual time sheet charges.

Drawing production is reported on the basis of the number of "N" size drawings produced. An "N" size drawing is the normal TVA standard size which measures 26 by 37 inches inside the borderline and contains 6.68 square feet of drawing area. For reporting purposes, all other size drawings produced are converted into equivalent "N" size drawings in direct ratio of their square foot areas.

In computing the amount of time on this chart, 168 hours is considered as a man-month. Productive time chargeable to the man-month cost of the drawings includes all time spent on supervision, engineering design, drawing, checking, and procurement work. Nonproductive work such as time spent on final design reports, special assignments, field changes and cleanup, and certain maintenance work is not included in arriving at the cost of the drawings on a man-month basis. The chart shown in figure 362 indicates that the (periodic) monthly man-month rate per drawing for the Mechanical Design Branch for fiscal years 1954 and 1955 (24 months) ranged from a low of 0.9 to a high of 1.6. The cumulative or average rate was 1.18 man-months per drawing over this same 2-year period during which time 2,131 drawings were produced. These drawings included those prepared for all hydro and steam plant projects and miscellaneous structures. Design production data presented on the chart are based on the unit of man-months rather than

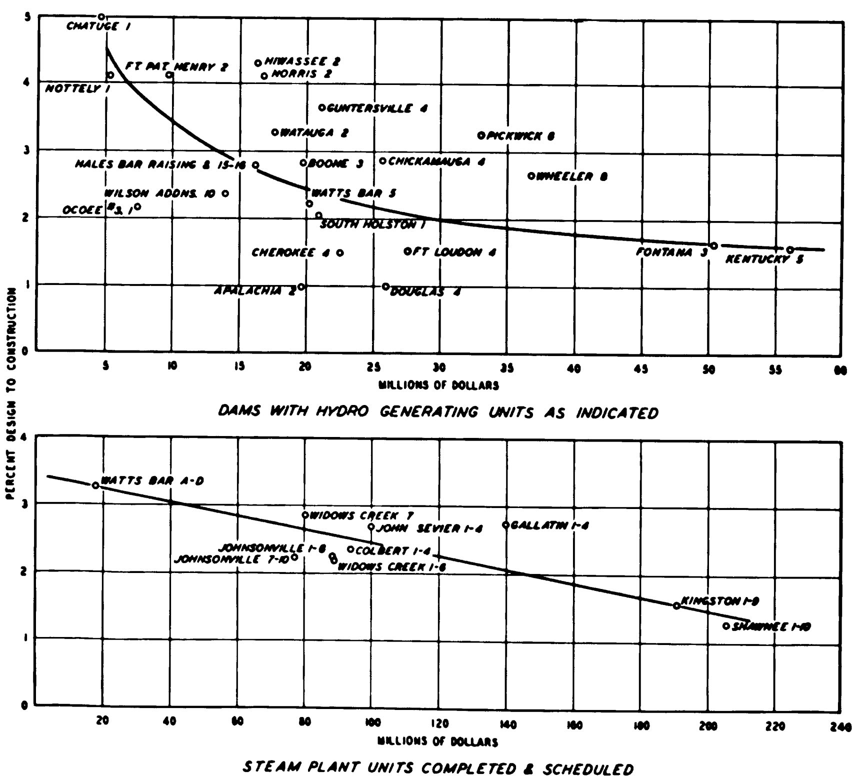

FIGURE 363.—*Percent design cost to project construction cost.*

actual dollars, due to variation in salary levels throughout the years during which the work was performed.

A reasonable measure of design economy is obtained by comparing design costs on a percentage basis with the actual direct construction costs of the projects. In figure 363 the top curve indicates the percent of design cost to construction cost for the 20 TVA-built dams and the unit additions to 2 acquired dams. Seventy-six hydroelectric unit installations are included. A similar cost comparison curve is also shown at the bottom in figure 363 covering 8 steam plants with a total of 52 generating units.

ACKNOWLEDGMENTS

The contents of this volume represent the individual and combined efforts and experience of many engineers in carrying out the program for the development of the Tennessee Valley. The report was compiled and edited by H. J. Petersen, Head Mechanical Engineer, and by R. M. Gardner, his successor, both of whom wrote large portions of the text.

Descriptive matter and illustrations in chapters 1 and 2 have been taken, for the most part, from published technical reports of TVA. The material in appendixes A to E is largely drawn from current standards, specifications, operating instructions, and test reports prepared by the Mechanical Design Branch.

The material in chapters 3 and 4 covering hydraulic turbines and governors, respectively, was prepared by C. L. Norris and J. E. Kirkland, Mechanical Engineers. Other specialized portions of the text compiled or written by other mechanical engineers include: chapters 7 and 8 by J. P. Wooten, chapters 9 and 17 by C. W. Bolieau, chapters 10 and 13 by R. C. Pletz, chapter 11 by J. W. Marshall, chapter 12 by L. W. Snyder, chapter 14 by B. S. Montgomery, and tabular data in chapter 15 by R. M. Stewart.

The report was produced under the general direction of the Chief Engineer, C. E. Blee, and his successor, Geo. K. Leonard; R. A. Monroe, Chief Design Engineer; and Harry Wiersema, Assistant to the Chief Engineer. Final editing and publication were carried out under the immediate supervision of John C. Voorhees, Office of the Chief Engineer, by Jack W. Hind, Civil Engineer, and by M. Helen Lambert, A. Lionel Edney, and Jean L. DeMarcus of the editorial staff.

Valuable assistance is acknowledged from many engineers and assistants including F. W. Ray, Chief, Thomas Benson, and Joe B. McNew of the Drafting and Service Branch, in preparing illustration material; C. C. Lindsay, Mechanical Engineer, and Q. R. Carroll, Central Map and Drawing Services, in selecting photographs and illustrations; and Carol McIntyre, secretary, in transcribing, tabulating, and typing the greater portion of the manuscript.

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* TVA, or former TVA, staff member.

5. *The Hiwassee Valley Projects:*
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Appendix A

HYDRAULIC TURBINE AND GOVERNOR DATA

Appendix A includes a compilation of selected data on hydraulic turbines, governors, turbine inlet valves, and hydro generating units purchased and installed by TVA as of January 1, 1958. The first specification in this appendix covering the invitation to bid for the Fort Patrick Henry project hydraulic turbines and governors is complete and includes all the general clauses and data customarily used in making up a bid document of this type. Such general information which is included with this first specification is omitted from all other specifications in this appendix and succeeding appendixes. These omitted items namely are (1) Invitation, Bid, and Acceptance form which is the first page of the bid document as shown in figure 364, (2) Bid Schedule except in appendix C, (3) Shipping Dates, (4) Shipping Data, (5) Labor and Materials Cost Adjustment Data, (6) General Conditions, (7) Special Conditions, and (8) Walsh-Healy Act. These general clauses were those in effect at the time this bid document was issued and are therefore not necessarily the latest wording for such clauses in current use.

The sections contained in this appendix are: *Pag*

INVITATION TO BID AND SPECIFICATIONS—HYDRAULIC TURBINES AND GOVERNORS—FORT PATRICK HENRY UNITS 1 AND 2

(Reference drawings not included in this report)

See figure 364 for first page of bid document.

BID SCHEDULE

Item No.	Articles or services	Quantity	Unit	Unit price	Amount
	SCHEDULE I				
	F.o.b. cars, TVA siding, Kingsport, Tenn. (except shaft which shall be f.o.b. cars generator manufacturer's plant).				
	Furnishing hydraulic turbines and governing systems for Fort Patrick Henry power plant, in accordance with the enclosed specification No. 4363 and drawings mentioned therein. Contingent upon making separate awards for items 1 and 2.				
1	Two turbines, including delivery to the generator manufacturer of partially completed turbine shaft as set forth in sec. 20 of the specification.	....	Lump sum......	....	....
2	Two governing systems complete	....	.....do..........	....	....

BID SCHEDULE—Continued

Item No.	Articles or services	Quantity	Unit	Unit price	Amount
	SCHEDULE II. *Alternate Bids*				
	F.o.b. cars, TVA siding, Kingsport, Tenn. (except that shaft shall be f.o.b. cars generator manufacturer's plant). Furnishing hydraulic turbines and governing systems for Fort Patrick Henry power plant, in accordance with the enclosed specification No. 4363 and drawings mentioned therein. Contingent upon making a single award for items 1 and 2.				
1	Two turbines, including delivery to the generator manufacturer of partially completed turbine shaft as set forth in sec. 20 of the specification.	--------	Lump sum------	--------	----------
2	Two governing systems complete	--------	-----do	--------	----------
	SCHEDULE III				
	Miscellaneous items supplementary to all turbine bids under schedules I and II—F.o.b. cars, TVA siding, Kingsport, Tenn.				
3	Spare parts as set forth in sec. 77 of the specification	--------	-----do	--------	----------
4	Price adjustment for increase or decrease in length of shaft, as set forth in sec. 78 of the specification.	--------	Lin. ft	--------	----------
5	Price adjustment for each pound of metal added or omitted because of change in length of pit liner as set forth in sec. 79 of the specification.	--------	Pound	--------	----------
6	Two generator inspection platforms as set forth in sec. 80 of the specification.	--------	Lump sum	--------	----------
	SCHEDULE IV. *Services*				
7	Services of erection engineers for turbine (see sec. 8 of Special Conditions).	--------	Each per day or fraction thereof.	--------	----------
8	Services of mechanics for turbines (see sec. 8 of Special Conditions).	--------	-----do	--------	----------
9	Services of erection engineers for governing system (see sec. 8 of Special Conditions).	--------	-----do	--------	----------
10	Services of mechanics for governing system (see sec. 8 of Special Conditions).	--------	-----do	--------	----------
11	Services of erection engineer for automatic greasing system (see sec. 8 of Special Conditions).	--------	-----do	--------	----------

Name of manufacturer:
Item 1 ______________________________
Item 2 ______________________________
Point of manufacture:
Item 1 ______________________________
Item 2 ______________________________
State weight and loaded dimensions of largest pieces for purpose of securing railroad clearances:

____
____
____
____

SHIPPING DATES

The Authority's schedule requires shipment of the various parts as follows:

	Unit 1 dates	*Unit 2 dates*
Preliminary drawings of draft tube and scroll case	Oct. 1, 1951	Oct. 1, 1951
Final drawings of draft tube and scroll case	Jan. 1, 1952	Jan. 1, 1952
Scroll case mandoor and frames	Sept. 1, 1952	Dec. 1, 1952
Draft tube liner	Dec. 1, 1952	Feb. 1, 1953
Embedded parts	Jan. 1, 1953	Mar. 1, 1953
Balance of turbine	Apr. 1, 1953	June 1, 1953
Shaft to generator manufacturer	Feb. 15, 1953	Apr. 15, 1953
Governor	July 1, 1953	July 1, 1953

Bidder shall indicate in the appropriate space below the *dates* on which he can ship the various parts:

	Unit 1 dates	*Unit 2 dates*
Preliminary drawings of draft tube and scroll case		
Final drawings of draft tube and scroll case		
Scroll case mandoor and frames		
Draft tube liner		
Embedded parts		
Balance of turbine		
Shaft to generator manufacturer		
Governor		

SHIPPING DATA

The Authority reserves the right to specify complete routing on all shipments; *provided, however*, such routing causes no additional cost to the contractor.

Always complete columns 1 through 6, unless otherwise stated on the schedule.

1 *Schedule or item No.*	2 *Estimated shipping weight*	3 *Method of shipment*	4 *Point of shipment*	5 *Railroad(s) on which you can load*	6 *No. of days after award for shipment*

DATA TO BE SUBMITTED WITH BID

***Bidder's specifications and drawings.*—Each bidder shall submit with his bid complete specifications and general drawings describing and illustrating the equipment he proposes to furnish. The information shall include all essential dimensions, the kinds of material to be used in each major part, with the chemical and physical properties of materials if other than those covered in detail in the Authority's specifications, and the following drawings and detailed data:**

TURBINE

1. General plans and sections showing all essential details of the proposed turbine settings, including all water passages.
2. General drawings of the turbine showing:
   a. Diameter of main shaft.
   b. Outside diameter of sleeves on main shaft.
   c. Diameters of wicket gate stems.
   d. Diameter of wicket stem bearing circle.
   e. Diameter of runner.
   f. Main guide bearing.
3. Outline drawing of the draft tube showing piers.

TENNESSEE VALLEY AUTHORITY
MATERIALS BRANCH
Chattanooga, Tennessee

INVITATION, BID, AND ACCEPTANCE

Date March 9, 1951

Acct. No. H-21-39

Project Fort Patrick Henry

Reqn. No. 658901

Order No. ______

Order Date ______

INVITATION

A quotation IN DUPLICATE is requested on the items listed below, subject to the conditions hereon and those attached hereto. Quotations will be received at this office until 10:00 a.m. EST, April 6, 1951, and will be opened and read in public.

TENNESSEE VALLEY AUTHORITY

fic By J. W. Almquist

BID

Date ______

In compliance with the above invitation for bids, and subject to all the conditions thereof, the undersigned offers, and agrees if this bid be accepted within ______ days (30 days unless otherwise stated) from the date of the opening, to furnish any or all of the items upon which prices are quoted, at the price set opposite each item.

Discounts will be allowed for payments as follows: 10 calendar days, ______ percent; 20 calendar days, ______ percent; 30 calendar days, ______ percent. Discounts will be deducted from the gross contract price unless otherwise qualified by the bidder on this form.

______ Bidder

______ Address

By ______ Title

Member of firm or person authorized to sign bid

Consign to- Tennessee Valley Authority,

Mail Invoice in DUPLICATE to Tennessee Valley Authority,

INVOICES MUST SHOW: Order number, requisition number, discount or terms of payment applicable, item number, description of article or service, quantity, unit price, total amount; and the original invoice must be certified as follows:

I certify that the above bill is correct and just and that payment therefor has not been received,

Payee ______ Per ______ Title ______

REQUISITION and ORDER NUMBER must be shown on all invoices, packages, shipping papers and correspondence.

ACCEPTANCE

Accepted as to items numbered ______

TENNESSEE VALLEY AUTHORITY

By ______

Total $ ______

Acknowledge receipt of this order. Please deliver in accordance with instructions the articles or services listed.

ITEM NO.	ARTICLES OR SERVICES	QUANTITY ORDERED	UNIT	UNIT PRICE	AMOUNT
	Design, fabricate, furnish, sell, and deliver Hydraulic Turbines and Governing Systems in accordance with TVA Specifications No. 4363, TVA Drawings No. 41N1 and No. 41N2, and all the terms and conditions included in this Invitation to Bid. Attachments which form part of this Contract (to be filled in where required): Form CR-1 Schedule of Prices (including Shipping Dates) Shipping Data Data and Guarantees Cost Adjustment Data General Conditions (back of Form 5050 and Form GC-4) Special Conditions Walsh-Healey Act TVA Specifications No. 4363 TVA Drawings: No. 41N1 No. 41N2 "The bidder represents that he____(has),_____(has not) employed or retained a company or person (other than a fulltime employee) to solicit or secure this Contract, and agrees to furnish information relating thereto as requested by the contracting officer."				

FOR TVA USE ONLY

Material Received 19		
G. B. L. No.		
Carrier's Charges: Paid $ Collect $		
Purchase Cost		
Cash Discount-or		
Carrier's Charges		
Total Cost		

I certify that the articles or services listed above have been received in quantity and quality specified except as noted.

Person receiving material — Approved as reported above

Delivered VIA	Truck: Vendor	Truck: TVA	Common Carrier: Rail Frt.	Rail Exp.	Mtr. Frt.	Air	Par. P.

TVA 5050(MAT-8-50)

FIGURE 364.—*Invitation, bid, and acceptance form.*

4. Outline drawing of the speed ring and scroll case showing principal dimensions.

5. Test curves of a homologous model turbine runner tested with draft tube similar to type proposed. These data shall include curves for unit horsepower, unit discharge, and efficiency plotted against sigma for the full range of heads as specified for this plant and curves for unit horsepower, unit discharge, and efficiency plotted against unit speed. These data shall cover the full range of gate opening. There shall also be furnished with the above data the name of at least one plant where a turbine homologous to the test runner is in operation giving the rated head, full gate horsepower, and rated speed. Bids not accompanied by these data may be rejected.

6. Estimated capacity and efficiency curves for the turbine when operating at the specified speed and under the heads at which the bidder's guarantees are made. Guaranteed performance points shall be clearly indicated.

7. Method of dismantling turbine, with necessary dimensions to determine conformance with crane clearances.

GOVERNOR

8. Description and drawings of the governor showing:
   a. General arrangement and dimensions of the proposed equipment.
   b. Illustrations or drawings showing the construction and arrangement of the actuator, the oil pumps and motors, the tanks, and piping.
   c. Description of the method of driving the flyball motor.
   d. Description of the method used for remote control and remote indication of the governor controls.
   e. Illustration or drawing showing the proposed arrangement of the instruments and controls to be mounted on the face of the actuator and cabinet with a list of such instruments and controls.

PHYSICAL DATA

Each proposal shall contain at least the following physical data:

TURBINE DATA

Maximum runaway speed at maximum head	______
Flywheel effect of rotating parts, lb.-ft.^{2}	______
Dimensions of gate servomotor cylinders, inches	______
Volume of two gate servomotor cylinders, cubic inches	______
Volume of runner-blade servomotor cylinder, cubic inches	______
Size of pipe connections to gate servomotor cylinder, inches.	______
Total net weight, pounds	______
Net weight of rotating parts, pounds	______
Hydraulic thrust at maximum head and normal speed, pounds.	______
Maximum diameter outer head cover, inches	______
Hydraulic thrust at maximum head and runaway speed, pounds.	______
Weight of rotating parts plus hydraulic thrust at maximum head and normal speed, pounds.	______
Diameter of runner, inches	______
Estimated grease required for turbine guide bearing, pounds per hour.	______

GOVERNOR DATA

Make, type, and size	______
Source of power for flyball drive	______
Minimum capacity of governor, ft.-lb. per second	______
Oil pump:	
Manufacturer	______
Type	______
Speed, r.p.m	______
Minimum capacity against 300-pound-per-square-inch gauge pressure, g.p.m.	______

Oil pump motor:
- Manufacturer ______
- Type ______
- Rating, hp ______
- Speed, r.p.m ______
- Overall dimensions of oil pump and motor ______ x ______ x ______. ______

Tanks and piping:
- Volume of pressure tank, cubic feet ______
- Overall dimension of pressure tank ______ x ______ x ______
- Volume of sump tank, cubic feet ______
- Overall dimensions of sump tank ______ x ______ x ______
- Size of oil piping for servomotors, inches ______
- Maximum velocity of oil in piping to servomotors, feet per second. ______
- Type and quantity of oil for the governor system ______

Actuator cabinet:
- Overall dimensions, twin cabinet ______ x ______ x ______
- Overall dimensions, single cabinet ______ x ______ x ______

TURBINE CAVITATION GUARANTEES

The undersigned bidder hereby guarantees that excessive cavitation will not occur in the runner of the turbine within 1 year from the date the turbine is placed in commercial operation provided that the turbine is not operated (see sec. 18):

1. More than 800 hours during the year at less than the minimum horsepower specified below or
2. More than 50 hours during the year at outputs greater than the maximum specified below.

Output horsepower		*Net head,*
Minimum	*Maximum*	*Feet*
		70
		65
		60
		55

The centerline of the distributor will be set at elevation 1,192 or 1½ feet below tailwater with a discharge of approximately 4,000 c.f.s. through the unit.

TURBINE CAPACITY AND EFFICIENCY GUARANTEES

The undersigned bidder hereby guarantees that when operating at a speed of 138.5 r.p.m. the turbine shall have capacities and efficiencies of not less than those set forth in the following tabulation for the net heads specified:

Net head, feet	Maximum horsepower capacity guaranteed	Guaranteed efficiency at—				
		Maximum horsepower guaranteed	25,000 hp.	20,000 hp.	15,000 hp.	10,000 hp.
70						
65						
61	25,000					
60						
55						

Leave efficiency guarantees blank when maximum horsepower capacity guaranteed is less than horsepower listed.

GOVERNOR PERFORMANCE GUARANTEE

The undersigned bidder hereby guarantees that when operating under a sustained isolated load the magnitude of the sustained speed oscillation caused by the governor will not exceed 0.3 of 1 percent of rated speed with speed droop set at or above 2 percent, and that the dead band at rated speed shall not exceed 0.06 percent of the rated speed at any load. He also hereby guarantees that

the performance of the governor will be such that upon sudden changes of load on the turbine and with movement of the turbine gates no faster than that specified, the speed change will be not greater than the following:

Load change, percent of rated capacity	*Speed change, percent*
Load on	
10	
25	
50	
Load off	
10	
25	
50	
100	

Above is based on a governor closure rate of 6 seconds and on a total WR^2 of 13,000,000 lb.-ft.^{2} for the revolving parts of the unit and a normal speed of 138.5 r.p.m.

LABOR AND MATERIALS COST ADJUSTMENT DATA

1. *General.*—Bidders shall submit their bids on the understanding that the lump sum price bid for complete performance of item 1 and/or item 2 of the contract is subject to adjustment for increases or decreases in labor and materials costs under the provisions of section 6 of the special conditions attached. The lump sum price which shall be subject to adjustment as to labor costs is fixed for this contract at 45 percent of said price as defined in section 6 of the special conditions attached. The portion of said lump sum price which shall be subject to adjustment as to materials costs is fixed for this contract at 35 percent of said price less the value of materials which are available or which will be available for use in performing this contract, and which were on hand with the contractor or which were on order at firm prices, at the date of contractor's bid; the bidder shall evaluate such material on hand or on order in the space provided below in paragraph 3.

2. *Allocation of labor costs.*—The bidder shall allocate in the following blanks the total amount of 45 percent of the contract price to the quarterly (3 month) periods during the continuance of the contract from the date of award (date of contract) until the completion date stipulated.

	Item 1	*Item 2*
First quarter	$ ________	$ ________
Second quarter	$ ________	$ ________
Third quarter	$ ________	$ ________
Fourth quarter	$ ________	$ ________
Fifth quarter	$ ________	$ ________
Sixth quarter	$ ________	$ ________
Seventh quarter	$ ________	$ ________
Eighth quarter	$ ________	$ ________
Ninth quarter	$ ________	$ ________
Tenth quarter	$ ________	$ ________
Eleventh quarter	$ ________	$ ________
Twelfth quarter	$ ________	$ ________

(The total of above columns shall equal 45 percent of the contract price.)

3. *Value of materials on hand and on order.*—The bidder shall, by completing the following blanks and subtracting (b) from (a), show the portion of the contract price which will be adjusted under the contract for materials costs at (c).

(a) 35% of the contract price .... $ ________
(b) The value of materials on hand and on order as described in Paragraph 1 .... $ ________

$ ________
(c) Total amount subject to adjustment as to materials ..... $ ________

4. The bidder shall allocate in the following blanks the amount set forth in 3(c) above to the quarter periods during the continuance of contract from the date of award until the completion date stipulated in the contract.

	Item 1	Item 2
First quarter	$ ______	$ ______
Second quarter	$ ______	$ ______
Third quarter	$ ______	$ ______
Fourth quarter	$ ______	$ ______
Fifth quarter	$ ______	$ ______
Sixth quarter	$ ______	$ ______
Seventh quarter	$ ______	$ ______
Eighth quarter	$ ______	$ ______
Ninth quarter	$ ______	$ ______
Tenth quarter	$ ______	$ ______
Eleventh quarter	$ ______	$ ______
Twelfth quarter	$ ______	$ ______

(The total of above columns shall equal the amount set forth in 3(c).)

5. The foregoing allocations of labor and materials costs (paragraphs 2 and 4) and the valuation of materials on hand and on order (paragraph 3) shall be made by the bidder only after thorough study and investigation and shall represent the bidder's best effort to estimate actual operations under the contract and actual values of materials. This data sheet shall be signed by the bidder, in the space provided below, and, upon award, shall be made a part of the contract.

Name ______________________

By ______________________

Date ______________________ Title ______________________

GENERAL CONDITIONS

1. *Bid documents.*—These conditions, together with those on back of form TVA 5050, the special conditions, and other documents attached hereto constitute a part of the bid and contract and should be carefully examined by the bidder before submitting his bid. Bids that do not comply with these conditions will be subject to rejection.

2. *Bid form.*—All bids must be based upon the specifications and drawings, if any, and must be made upon the blank forms of proposal which are hereto attached. The form of proposal must not be changed. All appropriate entries of bid prices and other data shall be made in the several blank spaces provided therefor.

3. *Experience and facilities.*—Each bidder may be required to furnish evidence of experience in the manufacture and successful operation of similar equipment to that required by this contract. He may be required to furnish satisfactory evidence that he has, in the judgment of the Authority, adequate plants, facilities, equipment, financial resources, business and technical organization, and working capital to begin the work promptly and prosecute it vigorously in such manner as to secure completion within the time specified.

4. *Changes.*—The contracting officer may at any time, by written order, and without notice to the sureties, make changes in the drawings and specifications and within the general scope of the contract, if such changes cause an increase or decrease in the amount due under this contract, or in the time required for its performance, an equitable adjustment will be made in either or both, and the contract shall be modified in writing accordingly. All claims for adjustment under this paragraph must be asserted within ten (10) days from the date the change is ordered, and in the meantime the contractor shall proceed with the work so changed.

5. *Inspection.*—All materials and workmanship shall be subject to inspection and test at all times and places, and, when practicable, during manufacture or construction. The Authority shall have the right to reject articles or work which contain defective materials or workmanship, or which do not comply with the specifications, and to require their replacement or correction in accordance with the contract, by and at the expense of the Contractor promptly

after notification of rejection. If the inspection or test is made on the premises of the contractor, the contractor shall furnish, without additional charge, all reasonable facilities and assistance therefor.

Inspection and acceptance shall not be conclusive as regards latent defects, fraud, or such gross mistakes as amount to fraud. Inspection and acceptance or rejection of the material or work shall be made as promptly as practicable, but failure to inspect and accept or reject materials or work shall not impose liability on the Authority for such materials or work as are not in accordance with the specifications. Neither inspection, or anything disclosed thereby, or acceptance, shall affect any warranty of the contractor. Reference is made to the specifications for further provisions, if any, as to inspection.

The contractor shall keep the engineer informed in advance of the time of starting and the progress of the work in its various stages so that arrangements can be made for inspection.

The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where materials or equipment are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such materials or equipment.

6. *Responsibility for materials and work.*—The risk of loss as to all materials and work covered by this contract shall be upon the contractor until delivery at the delivery point designated in the contract regardless of where inspection thereof is made by the Authority: *Provided, however,* That if the Authority elects to have shipment made on a Government bill of lading pursuant to paragraph on *Use of Government Bill of Lading*, risk of loss shall be upon the contractor only until completion of delivery of the materials to the originating carrier. As to articles, materials or work rejected by the Authority pursuant to the terms of the contract, the risk of loss thereof shall be restored to the contractor as of the time the Authority notifies the contractor that the same have been rejected and are being held for disposition.

All materials and work covered by partial payments made shall thereupon become the sole property of the Authority, but this provision shall not be construed as relieving the contractor from the sole responsibility for the care and protection of materials and work upon which payments have been made or the restoration of any damaged work until delivery is accomplished, or as a waiver of the right of the Authority to require the fulfillment of all of the terms of the contract.

7. *Disputes.*—Except as otherwise specifically provided in this contract, all disputes arising under this contract shall be decided by the contracting officer or his duly authorized representative, whose decision shall be final and conclusive upon the parties hereto. In the meantime, the contractor shall diligently proceed with the work as directed.

8. *Waivers.*—No waiver of any breach of this contract shall be held to be a waiver of any other or subsequent breach. All remedies afforded the Authority in this contract shall be taken and constructed as cumulative; that is, in addition to every other remedy provided herein or by law.

9. *Claims and protests.*—If the contractor claims compensation for any damages alleged to have been sustained by reason of any act or omission of the Authority, or any of its agents, or takes exception to any ruling, measurement, classification, calculation, or any definition or other act of the Authority, he shall, within ten (10) calendar days after the arising of the cause for any such claim or protest, file a formal written protest with the Authority, and shall, on or before the tenth day of the month succeeding that in which any such damage shall be claimed to be sustained or cause for any such claim shall have arisen, file with the contracting officer an itemized statement of the details and amount of such damage or claim, or be considered as having waived all claims on account of the matter excepted to or complained of, and shall not be entitled to any payment on account thereof.

10. *Method of shipment and use of Government bill of lading.*—The Authority reserves the right to specify the method of transportation and the exact routing to be used, and/or to require the use of a Government bill of lading on any shipment to be made hereunder. If any shipment is made on a Government bill of lading the Authority, on an f.o.b. destination order or contract, shall be entitled to deduct and retain from any payment due the

vendor full commercial transportation charges and the Federal transportation tax thereon which the vendor would have had to pay for the same shipment if made on a commercial bill of lading by the method of transportation stated by him in his bid, whether or not shipment is actually made by such method; or if any prepaid shipment moves at the Authority's request by a method of transportation different from that stated by the vendor, an adjustment shall be made for any difference in transportation charges: *Provided, however,* That in neither case shall the amount so retained on this adjustment include such increases or decreases in transportation charges which devolve upon or to the Authority in accordance with the provisions of the *Changes in Freight Rates* clause.

11. *Changes in freight rates.*—If this contract is awarded and performed upon the basis of a price or prices which include transportation charges to destination, with the exception noted below, any increase in the freight rates applicable to the shipment of the finished and delivered articles covered by the contract occurring between the date of contractor's bid and the date of shipment specified in the contract, including any extension thereof in accordance with the *Delays and Remedies* provision included herein, shall be borne by the Authority, and any decrease in said freight rates occurring between the date of contractor's bid and the date of actual shipment shall be credited to the Authority. Billing shall be at contract prices and any decrease or allowable increase in transportation charges resulting from changes in freight rates shall be based upon actual shipping weights and shown as a separate item on the invoice: *Provided, however,* That this provision with regard to changes in freight rates shall not be applicable to contracts which provide for payment of price in effect at time of shipment, or contracts similarly qualified as to price, or to contracts which include a zone price, said prices being deemed to reflect all changes in freight rates occurring prior to or on date of shipment.

12. *Prepayment of transportation charges.*—Unless shipments are required to be made on Government bills of lading the vendor must pay all transportation charges to the carrier at shipping point regardless of f.o.b. point, as TVA has no means of paying charges on collect shipments at destination and cannot accept them. All shipments on f.o.b. origin purchases on which vendor prepays transportation charges and adds them to his invoice must move by the carrier or carriers over whose line or lines the lowest available charge would apply for the method of transportation specified. Failure to observe this requirement may delay the receipt of shipments and consequently the payment of invoices.

13. *Risk of loss or damage in transit.*—If the contract is awarded upon the basis of a price or prices which include transportation charges in whole or in part to destination, title to the goods and risk of loss or damage shall remain in the contractor until delivery in acceptable condition by the carrier at destination notwithstanding the inclusion in the quotation of such technical expressions as "f.o.b. origin with freight prepaid," "f.o.b. origin with freight allowed," or variations of such expressions, unless shipment is made on Government bill of lading furnished by the Authority.

SPECIAL CONDITIONS

1. *Delivery.*—Time is of the essence of the contract. The Authority's program calls for delivery of this equipment as stated in the schedule.

2. *Shipping information.*—The contractor shall furnish copies of shipping bills or memoranda for each shipment of equipment, giving the designation mark of each piece, the number of pieces, the total weight, and the car initials and number to:

J. W. Almquist, Purchasing Agent, Division of Property and Supply, Tennessee Valley Authority, Lupton Building, Chattanooga, Tenn. 1 copy.

W. K. Seaman, Project Manager, Boone Dam, Tennessee Valley Authority, Johnson City, Tenn. 1 copy.

Chief Storekeeper, Boone Dam, Tennessee Valley Authority, Johnson City, Tenn. 2 copies.

3. *Engineer.*—Mr. H. J. Petersen, Head Mechanical Engineer, Tennessee Valley Authority, 204 Union Building, Knoxville, Tenn., has been designated

to represent the Chief Engineer in the fulfillment of the technical requirements of this contract, and correspondence relative thereto should be addressed to him.

4. *Inspection.*—Inspection will be made by the Tennessee Valley Authority, but such inspection shall not relieve the contractor for failure to meet the contract requirements. The Authority's inspection of shop work and witnessing of shop tests will be the responsibility of the Inspection and Testing Branch, and correspondence relative thereto should be addressed to P. J. Freeman, Head Materials Engineer, Tennessee Valley Authority, Knoxville, Tenn.

5. *Walsh-Healey Act.*—The attached representations and stipulations pursuant to Public Act No. 846, 74th Congress, are made a part of this contract.

6. *Consideration.*—The principal amount (item 1 and/or item 2 of schedule) hereinafter called "Contract Price" (not including any amount of compensation for erection engineers) shall be subject to increase or decrease to reflect increases or decreases in labor and material costs, in accordance with allocations stated by the successful bidder on the cost adjustment data sheets and the following provisions:

A. *Labor.*—The measure to be applied in adjusting the contract price as to labor on the foregoing labor portion of the contract price shall be the average straight-time hourly labor earnings of the hydraulic turbines industry as determined and reported by the Department of Labor, Bureau of Labor Statistics. The base with reference to which said labor cost shall be adjusted is the average straight-time hourly earnings so determined and reported as covering the month during which contractor's bid was made. The Authority shall obtain said reports, as soon as they are published, and shall calculate for each quarterly period the percentage by which the average straight-time hourly earnings for each quarterly period are greater or less than the said base. In that percentage, as to each quarter, the amount of the respective labor quota shall be increased or decreased, and in the amount of such increases or decreases, so computed, the contract price shall be increased or reduced, without regard to contractor's actual labor costs.

B. *Material.*—The measure to be applied in adjusting the contract price as to material on the foregoing material portion of the contract price shall be the average price per pound for materials for hydraulic turbines, as determined and reported by the Department of Labor, Bureau of Labor Statistics. The base with reference to which said material cost shall be adjusted is the index number so determined and reported as covering the month during which the contractor's bid was made. The Authority shall obtain said reports as soon as they are published, and shall calculate for each quarterly period the percentage by which the average of monthly index numbers for the quarterly period is greater or less than the said base. In that percentage, as to each quarter, the amount of the respective material quota shall be increased or decreased, and in the amount of such increases or decreases, so computed, the contract price shall be increased or reduced, without regard to contractor's actual material costs.

C. In the event that circumstances developing after the date of contractor's bid make the assigned quotas inequitable to either party in the light of actual operations under the contract, and quotas shall be revised as the parties may agree. In the event that contractor fails to complete performance of the contract within the time stipulated in said contract, the quotas for labor and materials shall be altered as the parties may agree in order that they shall equitably assign the material or labor portions of the contract price to all periods within the entire time required for complete performance of the contract, including the period of delay: *Provided, however,* That quotas for labor and materials shall not be altered for the contractor's benefit on account of delays in the completion of the contract which are not excused.

In computing the percentage of increase or decrease over the base hereinbefore provided for labor and material, percentages shall be calculated to the nearest one-tenth (1/10) of 1 percent (1%).

Payment for any increase, or any credit to the Authority for any decrease in the contract price to cover changes in the cost of labor and the cost of material, computed as aforesaid, shall be made or taken in the final payment provided for in section 6 hereof, subject to ability of the Authority to obtain the reports referred to above which are necessary for determining any increase or decrease.

7. *Terms of payment.*—Payments less such deductions as the Authority may be entitled to retain hereunder will be made as follows:

Within thirty (30) calendar days after date of notice of award, the contractor shall submit to the contracting officer a list of the various factors entering into the work to be performed under the contract and the proportionate parts of the total contract price allocated thereto, the aggregate of which parts shall equal the total contract price. These factors shall be subdivided into constituent parts representing, but not limited to, engineering and design, preparation for acquiring materials, materials, fabrication, assembly, and transportation. Such list of factors together with the allocation of the total contract price thereto shall be subject to the approval of the Authority and shall become a part of the contract when so approved.

Eighty-five (85) percent of the price of the materials accumulated and work done on any proportionate part of subdivision thereof allocated as described above, will be paid less previous payments thereon, within thirty (30) calendar days after receipt by the Tennessee Valley Authority of proper evidence, properly certified showing the percent of progress of work completed on said proportionate part of subdivision thereof.

The final payment including the remaining fifteen percent (15%) of the contract price will be paid within sixty (60) calendar days after acceptance of all equipment covered by this contract, provided that if through no fault of the contractor acceptance is delayed for more than ten (10) calendar months after date of shipment, the remaining fifteen percent (15%) will be paid within twelve (12) calendar months from date of shipment.

Such final payment, however, shall not relieve the contractor of any of his unfulfilled obligations under this contract.

Payment for services of erecting engineers and/or mechanics will be made monthly during the period of such services as required by the Authority.

Separate invoices must be submitted, in triplicate, for each payment.

8. *Services of erecting engineers and/or mechanics.*—The contractor shall, if required, furnish at such times and for such periods as required by the Authority, competent erecting engineers and/or mechanics as needed to supervise, direct, and be responsible for the installation and/or testing in the field of the equipment furnished under this contract. For the services of the erecting engineers and/or mechanics, the contractor will be paid the amount per day, or fraction of a day, including Sundays and legal holidays, stated in the bid schedule. The payment will cover the entire period of time that the erecting engineers and/or mechanics are in the service of the Authority, including not more than the time required to travel by the most direct rail route from the contractor's fabricating plant to the site of erection and return. Railroad and sleeping car fares and other necessary transportation expenses will be paid by the Authority (in accordance with TVA travel regulations) but no payment will be made for subsistence or other personal expense while en route or elsewhere. The contractor must take advantage of round-trip transportation rates. Receipts must be submitted for Pullman accommodations and other authorized miscellaneous expenses. The exact beginning and ending dates of the travel period must be shown on invoices. The Authority will furnish the contractor a copy of the above mentioned travel regulations on request.

9. *Patents and/or copyrights.*—The contractor shall hold and save the Authority, its officers, agents, servants and employees harmless from liability of any nature or kind, including costs and expenses, for or on account of any copyrighted or uncopyrighted composition, secret process, trademark, patented or unpatented invention, article or appliance manufactured or used in the performance of this contract, including their use by the Authority.

In furtherance of the contractor's obligations and not in limitation of the foregoing, the contractor shall at its own expense defend any suit instituted by any party against the Authority so far as it is based on the claim that any apparatus or part thereof furnished under this contract, or the Authority's use of such apparatus or part for the purposes for which it was designed and/or for such other purposes, if any, specified in this contract, constitutes infringement of any United States patent. The Authority shall give to the contractor immediate notice in writing of the institution of such suit, and shall permit the contractor, through its counsel, to defend the same, and shall give all requisite authority and all needed and available information and assistance to enable the contractor to do so. The contractor shall pay all damages and

costs finally awarded therein against the Authority by reason of such infringement, but the contractor shall not be liable under any compromise made without its consent. If in any such suit said apparatus or part or such use thereof by the Authority is held to constitute infringement and such use is enjoined, the contractor shall at its own expense procure for the Authority forthwith the right to use or continue using the said apparatus or part: *Provided, however,* That subject to the Authority's approval the contractor may at its sole expense replace said apparatus or part with non infringing apparatus or part, or modify it so that it becomes non-infringing.

10. *Guaranty.*—The contractor warrants that all materials, equipment, machinery, and workmanship furnished pursuant to this contract comply in all respects with the contract, and are free from latent and patent defects in materials, workmanship, and construction, and are suitable and adequate for the purposes for which they were designed and/or for such other purposes, if any, specified in this contract and guarantees that all equipment and machinery will give efficient service for a period of one (1) year after acceptance, under the specified conditions. If the contract or specifications provide for acceptance tests of the articles furnished, they are not to be deemed accepted by the Authority until they have passed such acceptance tests: *Provided, however,* That in no event shall this guarantee extend for more than eighteen (18) calendar months beyond the date of receipt of the articles by the Authority. The contractor further warrants, and upon demand will, at its own expense, defend the title to all materials, articles, or work furnished or done hereunder. The contractor further warrants that the same are free from any and all claims and demands in respect to the foregoing.

Any equipment which fails to meet the guarantees or other requirements of the contract may be rejected. If required by the Authority, the contractor shall proceed at once to make alterations or furnish new parts as may be necessary to meet the guarantees or other requirements. Any work in the power plant shall be done at times acceptable to the Authority. Operation by the Authority of the equipment or any part thereof shall not constitute any waiver of any of the Authority's rights under this contract or at law.

All expense of delivering, furnishing, and installing new parts or alterations to existing parts shall be borne by the contractor. This shall include the actual cost and usual overhead on any work which the Authority may do for the contractor: *Provided,* That any materials or machinery not furnished by the contractor, which must be removed to give access to the apparatus furnished by the contractor, will be removed and replaced by the Authority without cost to the contractor.

None of the foregoing shall be construed as relieving the contractor of any warranty implied by law.

11. *Available funds—Failure of Congress to appropriate funds.*—The Authority has allocated out of funds available for the fiscal year ending June 30, 1951, the sum of $50,000 dollars for payments under this contract. The Authority has requested or will request at the appropriate time that Congress appropriate sufficient funds for all of Authority's construction, operating, and administrative requirements during the subsequent fiscal years, including in such requests funds sufficient to make payments under this contract in accordance with the following schedule:

Fiscal year	*Amount*
1952	$500,000
1953	Balance

Should Congress fail to appropriate to the Authority's use for any fiscal year prior to the completion of the payments hereunder a sufficient part of the funds requested by the Authority for its construction, operating, and administrative requirements for said year to enable Authority, in the judgment of the contracting officer, to allocate for the purpose the amount required in said fiscal year for the fulfillment of this contract, the Authority may in its option terminate the contract by giving written notice to the contractor; and all balances due the contractor under the terms of the contract for work acceptably executed prior to the date of such termination will be paid, including retained percentages and a reasonable allowance for profit on the work performed but less

any proper deductions to which the Authority shall be entitled. Upon request of the contractor the Authority will take over at no cost to contractor all materials to be incorporated in the work for which partial payment is authorized, deductions being made for damage or unsatisfactory material. In the absence of instructions from the contracting officer within thirty (30) days after such termination, the contractor may remove all or part of the material or equipment from its plant, dispose of or store it on its own premises or elsewhere for the account and at the risk and expense of the Authority, using reasonable care for its transportation and preservation; and shall be paid by the Authority all reasonable costs and expenses paid or incurred by the Contractor for the protection, disposition, removal, storage and transportation (including delivery costs in and out of storage) of such property.

It is not the intention of this article in any event to limit the Authority's liability for payments hereunder to funds appropriated by Congress, but rather to establish as a basis for the termination of the contract by the Authority, in its option, the failure of Congress to appropriate funds requested by the Authority for the purpose of the contract.

WALSH-HEALEY ACT

The following representations and stipulations pursuant to Public Act No. 846, 74th Congress, are made a part of this contract:

(A) The contractor is the manufacturer of or a regular dealer in the materials, supplies, articles or equipment to be manufactured or used in the performance of the contract.

(B) All persons employed by the contractor in the manufacture or furnishing of the materials, supplies, articles, or equipment used in the performance of the contract will be paid, without subsequent deduction or rebate on any account, not less than the minimum wages as determined by the Secretary of Labor to be the prevailing minimum wages for persons employed on similar work or in the particular or similar industries, or groups of industries currently operating in the locality in which the materials, supplies, articles, or equipment are to be manufactured or furnished under the contract: *Provided, however,* That this stipulation with respect to minimum wages shall apply only to purchases or contracts relating to such industries as have been the subject matter of a determination by the Secretary of Labor.

(C) No person employed by the contractor in the manufacture or furnishing of the materials, supplies, articles, or equipment used in the performance of the contract shall be permitted to work in excess of 8 hours in any one day or in excess of 40 hours in any 1 week, unless such person is paid such applicable overtime rate as has been set by the Secretary of Labor: *Provided, however,* That the provisions of this stiuplation shall not apply to any employer who shall have entered into an agreement with his employees pursuant to the provisions of paragraphs 1 or 2 of subsection (B) of section 7 of an act entitled "The Fair Labor Standards Act of 1938": *Provided further,* That in the case of such an employer, during the life of the agreement referred to, the applicable overtime rate set by the Secretary of Labor shall be paid for hours in excess of 12 in any 1 day or in excess of 56 in any 1 week and if such overtime is not paid, the employer shall be required to compensate his employees during that week at the applicable overtime rate set by the Secretary of Labor for hours in excess of 8 in any 1 day or in excess of 40 in any 1 week.

(D) No male person under 16 years of age and no female person under 18 years of age and no convict labor will be employed by the contractor in the manufacture or production or furnishing of any of the materials, supplies, articles or equipment included in the contract.

(E) No part of the contract will be performed nor will any of the materials, supplies, articles or equipment to be manufactured or furnished under said contract be manufactured or fabricated in any plants, factories, buildings, or surroundings or under working conditions which are unsanitary or hazardous or dangerous to the health and safety of employees engaged in the performance of the contract. Compliance with the safety, sanitary, and factory in-

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spection laws of the State in which the work or part thereof is to be performed shall be prima facie evidence of compliance with this subsection.

(F) Any breach or violation of any of the foregoing representations and stipulations shall render the party responsible therefor liable to the United States of America for liquidated damages, in addition to damages for any other breach of the contract, in the sum of $10 per day for each such breach or violation, and a sum equal to the amount of any deductions, rebates, refunds, or underpayment of wages due to any employee engaged in the performance of the contract; and, in addition the agency of the United States entering into the contract shall have the right to cancel same and to make open market purchases or enter into other contracts for the completion of the original contract, charging any additional cost to the original contractor. Any sums of money due to the United States of America by reason of any violation of any of the representations and stipulations of the contract as set forth herein may be withheld from any amounts due on the contract or may be recovered in a suit brought in the name of the United States by the Attorney General thereof. All sums withheld or recovered as deductions, rebates, refunds, or underpayments of wages shall be held in a special deposit account and shall be paid, on order of the Secretary of Labor, directly to the employees who have been paid less than minimum rates of pay as set forth in such contracts and on whose account such sums were withheld or recovered: *Provided*, That no claims by employees for such payments shall be entertained unless made within 1 year from the date of actual notice to the contractor of the withholding or recovery of such sums by the United States of America.

(G) The contractor shall post a copy of the stipulations in a prominent and readily accessible place at the site of the contract work and shall keep such employment records as are required in the regulations under the act available for inspection by authorized representatives of the Secretary of Labor.

(H) The contractor is not a person who is ineligible to be awarded Government contracts by virtue of sanctions imposed pursuant to the provisions of section 3 of the act.

(I) No part of the contract shall be performed and none of the materials, articles, supplies or equipment manufactured or furnished under the contract shall be manufactured or furnished by any person found by the Secretary of Labor to be ineligible to be awarded Government contracts pursuant to section 3 of the act.

(J) The foregoing stipulations shall be deemed inoperative if this contract is for a definite amount not in excess of $10,000.

The stipulations above enumerated are not applicable in the following instances:

(A) Where the contracting officer is authorized by statute or otherwise to purchase in the open market without advertising for proposals;

(B) Where the contract relates to perishables, including dairy, livestock and nursery products; ("perishables" cover products subject to decay or spoilage and not products canned, salted, smoked, or otherwise preserved);

(C) Where the contract relates to agricultural or farm products processed for first sale by the original producers;

(D) Where the contract is by the Secretary of Agriculture for the purchase of agricultural commodities or the products thereof;

(E) Where the contract is with a common carrier for carriage of freight or personnel by vessel, airplane, bus, truck, express, or railway line, where published tariff rates are in effect;

(F) Where the contract is for the furnishing of service by radio, telephone, telegraph, or cable companies, subject to the Federal Communications Act of 1934.

SPECIFICATION NO. 4363

GENERAL PROVISIONS

SECTION 1. *The requirement.*—The work covered by these specifications comprises designing, furnishing, and delivering two 25,000-horsepower, vertical-shaft hydraulic turbines of the propeller-runner type with automatically adjustable runner blades; two oil-pressure governing systems for the two turbines; constructing and testing a model turbine; together with certain other work as hereinafter set forth, all for the Fort Patrick Henry power plant.

The contractor shall furnish all the materials and do all the work required for such of the items of the bid schedule as are included in the contract, in strict accordance with these specifications.

SEC. 2. *Description of the power plant.*—The Fort Patrick Henry power plant is located on the South Fork Holston River in Sullivan County, Tenn., about 2.5 air miles southeast of Kingsport, Tenn. There will be a railroad siding in the Clinchfield railroad yards at Kingsport with necessary facilities for unloading material.

The power plant substructure will constitute a section of the dam and will be designed for an installation of two similar hydroelectric generating units, and these specifications cover their hydraulic turbines and governors.

Erecting space will be provided in the service bay at the shore end, and the units will be serviced by an overhead crane of sufficient capacity.

The turbines will be direct-connected to umbrella-type electric generators which will be rated 20,000 kv-a. normal, 3 phase, 60 cycles, 13,800 v. The station electric service will be 440 v., 3 phase, 60 cycles, and there will be a 250-v. storage battery to supply direct current for control circuits.

SEC. 3. *The engineer.*—Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the Engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

SEC. 4. *Authority's drawings.*—The work is shown on the accompanying set of two drawings of the Authority, which bear the general title "Fort Patrick Henry Powerhouse" and individual designations as follows:

Drawing No.	*Plan*
41N1	General Arrangement
41N2	General Arrangement Plans

Such supplementary drawings, correcting or further detailing the above, as may be necessary, will be furnished by the Authority during the progress of the work.

The Authority will be responsible for the correctness of its design, but the contractor shall carefully check all dimensions and quantities on drawings and schedules furnished by the Authority, and shall advise the Engineer of any errors or omissions discovered.

The Authority will furnish the contractor, without charge, necessary copies of the contract and specifications, and such number of prints of the Authority's drawings as may reasonably be required for the work.

SEC. 5. *Drawings to be furnished by the contractor.*—The contractor shall furnish to the engineer prints of assembly and detail drawings, wiring diagrams, and data of the work in such number and detail as necessary for the installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.

Such drawings shall include, but shall not be limited to, the following:

a. Preliminary and final detail drawings of the parts of the draft tubes and scroll cases designed by the contractor.

The preliminary drawings shall show the outline dimensions. The final detail drawings shall show, in addition to the outline dimensions, cross sections

with dimensions in each case, in such number and detail, as requested by the engineer, sufficient for the design of the concrete forms.

b. Foundation drawings of all parts set in or coming in contact with the concrete substructure, showing method of erecting, and of supporting and anchoring them in the concrete.

c. Detail drawings of all parts embedded in concrete.

d. Detail drawings of all parts connecting to or related to equipment supplied by other manufacturers or to equipment furnished by the Authority.

e. Drawings of all piping, wiring diagrams, and drawings showing methods of lubricating parts.

f. Detail drawings of all parts for which adjustment is provided or which are subject to wear.

g. Assembly drawings showing plans and sections of the entire turbine.

h. Subassembly drawings showing plans and sections of the principal component parts of the turbines including:

(1) Gate operating cylinders or servomotors.
(2) Main turbine shaft and guide bearing with housing and stuffing box.
(3) Gate operating mechanism, including shifting ring, links, levers, breaking pins, guide vanes, and guide vane bearings.
(4) Runner assembly, shaft coupling, runner servomotor and runner-blade operating mechanism.
(5) Detail drawings of top cover plates.
(6) Detail drawings of oil head and support.

i. Detail of drains and air vents, platforms, stairways, and guards.

j. Assembly drawings showing plans and sections of the governing systems.

k. Subassembly drawings, cuts, or illustrations as are necessary to show the arrangement and the functioning of the several parts of the governing systems.

l. Piping and arrangement drawings of the governing systems and accessories.

m. Foundation drawings of the governors and oil pressure tanks.

n. Detail drawings of the oil pressure tanks.

o. Detail drawing of the front of the governor cabinets showing the location and size of the instruments mounted on them.

p. Detail drawing of the governor cabinets.

q. Wiring diagrams showing electrical connections for the governing systems, and for electrical equipment and instruments.

Drawings shall show the materials, dimensions, finish, fits, clearances, tolerances, bolting, and such other information as necessary to demonstrate compliance with the requirements of the specifications.

Within 30 days after notice of award of the contract, the contractor shall submit to the engineer four copies of a list of drawings to be submitted by him, identifying each by serial number and descriptive title and giving expected date of submission. The list shall be revised and extended as necessary during the progress of the work.

The contractor shall permit the engineer to examine such of the contractor's shop drawings as may be necessary to determine the sufficiency of the contractor's design, and the contractor shall furnish the engineer with copies of such of his design data as may be required for that purpose.

Six prints of each drawing and diagram shall be submitted to the engineer for approval and in such sequence that he will have all information necessary for checking.

The engineer will, as soon as possible after receipt of prints of drawings submitted for approval, return one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Correction."

The contractor shall make the required corrections on drawings marked "Approved with Corrections as Noted" or "Returned for Correction," and he shall resubmit prints for approval in the same routine as before. Time required for such correction of drawings and resubmission of prints shall not entitle the contractor to any extension of time but the engineer will review and return such prints as promptly as possible.

Any work done or material ordered by the contractor prior to receipt of drawings marked "Approved" or "Approved with Corrections as Noted" by the engineer shall be at the contractor's risk.

After print of any drawing has been returned marked "Approved," the contractor may release to his shop for production, all parts covered by the approval, and similarly he may release to his shop for production, if so advised by the engineer at the time, parts covered by any print returned marked

"Approved with Corrections as Noted." When the approval covers an assembly or group of parts, the contractor shall furnish one print of each shop drawing of such parts to the Authority's inspector at his plant and a second print of each such shop drawing to the engineer.

Drawings of which prints are to be furnished shall be made in a manner to give clear, permanent reproductions. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract, and shall be signed by a responsible representative of the contractor.

Approval by the engineer shall not relieve the contractor of responsibility for the correctness of the drawings furnished by him.

If, at any time before the completion of the work, changes are made necessitating the revision of approved drawings, the contractor shall make such revisions and proceed in the same routine as for the original approval.

Before field erection starts, and upon notification by the engineer, three complete sets of all approved drawings shall be furnished for use by the field construction forces.

Upon completion of all work, the contractor shall furnish the Authority one set of vandyke negatives on thin paper and two complete sets of prints (one of which shall be on cloth) of all drawings approved by the engineer, including all corrections and revisions made up to the time of completion of the work.

SEC. 6. *Work to be done and material to be furnished by the Authority.*— The Authority will construct the power plant substructure with the turbine settings, including the water passages, in accordance with the designs shown on the Authority's drawings mentioned in section 4.

The Authority will unload and will transport the turbines and governors from the point of delivery to the site; will install them under the supervision and direction of the contractor's erecting engineers; will do the necessary field welding, drilling, and reaming of holes; and will make the capacity tests of the turbines and the tests of the governors after installation is complete.

The Authority will furnish and install the following miscellaneous accessories:

a. All piping outside the speed rings and outside the turbine pits, except the following:

(1) The piping and connections to the pressure and vacuum gages furnished by the contractor.

(2) The governor oil supply piping to the turbine gate servomotors, the governor oil supply piping and drains to the oil head, and all restoring cable piping.

b. All electrical connections, and all alarms, signals, and electrical devices outside the turbine pits, except as specified to be furnished with the governors.

c. Instruments, gauges, and the like as required for the turbine tests for capacity.

d. All governor oil except governor dashpot oil.

SEC. 7. *Work to be done and materials to be furnished by the contractor.*— The contractor under item 1 shall design, furnish, and deliver the turbine complete with all necessary auxiliary equipment, piping, and accessories required for satisfactory operation and maintenance and for convenient installation within the limits given below, unless otherwise specified in section 6:

a. Up to the face of the generator shaft half-couplings, at elevation 1204, including the oil supply heads and necessary piping and connections to the runner-blade servomotors.

b. Up to the top of the turbine pit liners, at elevation 1206.

c. Down to the lower end of the draft tube liners, a distance of 17 feet below the center line of the runner.

d. Including piping within the turbine pits, gauges, and accessories for the lubrication of the turbine guide bearings.

e. Including pressure and vacuum gages with piping and fitting for mounting in pit.

f. Including turbine guide bearing thermometers to be mounted on the governor cabinet.

g. Including atmospheric air vent valves and connections, compressed air piping connections to outside the turbine pits for depression of water level in the draft tubes to motor the units, and necessary drains.

h. All stairways, platforms, railings, and guards within the turbine pits, not otherwise provided for.

i. All bolts, anchor bolts, eyebolts, leveling jacks, jackscrews, gauges, rivets, templates, wrenches, special reamers, special tools, support for erection of runner, and special equipment needed for erecting and dismantling the equipment.

The contractor under item 2 shall design, furnish, and deliver the governing systems complete with all necessary auxiliary control mechanisms, restoring mechanisms, oil supply systems, pumps, piping, tanks, gauges, instruments, foundation bolts, special tools, and all accessories required for satisisfactory operation and maintenance, and for convenient installation. He shall furnish the valves for controlling the adjustable blade runners, the necessary supply and drain piping and connections to the oil supply heads, and the necessary piping and connections to the turbine gate servomotors.

The contractor, under the other items included in the contract, shall design, furnish, and deliver the work as stipulated and specified.

SEC. 8. *Contractor to cooperate with others.*—The contractor shall cooperate with the manufacturer of the generator and the manufacturers of other related equipment in the mutual exchange of drawings, dimensions, templates, gauges, and other information to the extent necessary to ensure the complete coordination of the design, arrangement, and manufacture of all related parts. Copies or prints of all data so exchanged shall be furnished to the engineer.

SEC. 9. *Materials and workmanship.*—Materials used in the work shall be new, and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

Where the characteristics of any material are not explicitly specified, approved material meeting the requirements of the appropriate specifications of the American Society for Testing Materials or other recognized standard shall be employed.

Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable except as otherwise noted.

Incidental fittings, fixtures, accessories, and supplies shall be new, of approved manufacture, and of standard first-grade quality.

Castings shall be true to drawings, homogeneous, free from objectionable nonmetallic inclusions and excessive segregation of impurities or alloys.

A casting having any dimension less than called for in the drawings, sufficient to impair its strength by more than 10 percent or to increase the stresses to above the limits specified, shall be rejected.

No casting shall be repaired without the approval of the engineer. Castings to be repaired by welding shall be chipped to sound, clean metal, but if such chipping reduces any stress-resisting cross section more than 20 percent, the castings may be rejected. Castings repaired by welding after annealing shall be reannealed, if required.

SEC. 10. *Access to work.*—The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such equipment or materials.

The contractor shall furnish suitable office space, equipment, and telephone facilities to enable the Authority's representative to perform his official duties.

SEC. 11. *Shop inspection and material orders.*—No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

The contractor shall, at his own expense, prepare specimens and perform tests and analyses in accordance with standard practice, as required to demonstrate conformance of the various materials to the pertinent specifications, under the direction and in the presence of the inspector. The contractor shall, when requested, furnish to the engineer certified test reports in triplicate of all required tests and analyses.

The contractor shall also furnish to the engineer test pieces and samples for independent analysis and test, as requested.

The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

The contractor shall furnish to the engineer and to the contracting officer a list of subcontractors and vendors with whom orders are to be placed for materials or equipment which will enter directly into the work of this contract. Triplicate copies of material or equipment orders and lists of contractor's stock material or equipment required in this contract shall be furnished to the engineer with one copy to the contracting officer.

All orders and stock lists shall state the specification designation under which the material is to be furnished, and shall bear reference to the drawing and part number, if any, pertinent thereto. Orders shall also state that material is subject to inspection and testing by the Authority, and shall show the required date of delivery of the material to the contractor's plant.

The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications, and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

SEC. 12. *Marking.*—All parts or units of assembly shall be marked or tagged with piece marks. Marks shall be in accordance with approved erection drawings, shall be clearly legible, and so placed as to be readily visible when the part is being erected in the field. All pieces weighing more than one ton shall have the approximate weight marked thereon.

Connecting parts, assembled in the shop, shall, before dismantling for shipment, be match-marked to facilitate erection in the field. The location of the match marks shall be clearly indicated on erection drawings furnished by the contractor. All parts or assembly of parts shall also be so marked as to identify them with this contract.

SEC. 13. *Preparation for shipment.*—The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

The turbine shafts, under item 1, shall be shipped by the contractor, at his own cost and risk, to the generator manufacturer. The delivery of the shafts from the plant of the generator manufacturer to the field will be made by the generator manufacturer without cost or risk to the contractor.

ITEM 1. TWO 25,000-HORSEPOWER TURBINES

SEC. 14. *Capacity of turbines.*—Under item 1 the contractor shall design, furnish, and deliver two 25,000-horsepower, vertical-shaft hydraulic turbines of the propeller-runner type with automatically adjustable blades. Direction of rotation shall be counterclockwise when viewed from above.

Each turbine shall have a capacity of not less than 25,000 horsepower under a head of 61 feet without exceeding the cavitation limit with tailwater at elevation 1195. The maximum full-load operating head will be approximately 70 feet, and the average operating head will be approximately 67 feet. The turbines shall be designed to have their maximum efficiency under a head of approximately 67 feet. Each turbine shall be designed and constructed to operate at any gate opening and under any head between 58 feet and 75 feet, inclusive.

The normal operating speed of the turbines shall be 138.5 revolutions per minute. The center line of the distributors shall be at elevation 1192.

The output of each turbine under various heads will be limited to those stipulated by the contractor in his cavitation guarantees, but will not exceed 30,000 horsepower (the capacity of the generator), except as otherwise mentioned in the specifications.

SEC. 15. *Operating heads for the turbines.*—The turbines will be operated under the conditions of head and of headwater and tailwater levels as follows:

Head:	
Normal	67 Feet
Maximum	70 Feet
Minimum	61 Feet
Headwater level:	
Normal	Elevation 1261.5
Maximum	Elevation 1263.0
Minimum	Elevation 1258.0
Tailwater level:	
Normal, 5,000 c.f.s	Elevation 1194.5
Maximum, 150,000 c.f.s	Elevation 1229.0
Maximum normal, 7,500 c.f.s	Elevation 1197.0
Minimum:	
2,000 c.f.s	Elevation 1191.0
500 c.f.s	Elevation 1188.0

Design and construction of each turbine

SEC. 16. *General.*—The contractor shall make and shall be responsible for the design of the work included in the contract. It shall be a coordinated, adequate, and neat design, fulfilling the requirements of the specifications and conforming to the best engineering practice. The design shall conform to the dimensions of the power plant structure and to the capacity of the 225-ton gantry crane, as shown on the accompanying Authority's drawings. The design shall be suitable for convenient transportation, erection, operation, and maintenance of the equipment.

In the design of the turbines, each part shall be so proportioned that the maximum unit stresses therein, resulting from any operation condition, shall not exceed one-third the elastic limit or one-fifth the ultimate strength of the material, whichever be the lesser, except as hereinafter specified. At the breaking point of a yielding link or shearing pin, a unit stress not to exceed two-thirds the elastic limit will be permitted in the wicket gates, the gate stems, and the gate operating levers. In cases of temporary overload as described in the section of these specifications entitled "Turbine Operating Requirements," unit stresses not exceeding one-half the elastic limit will be permitted.

Unit stresses in cast iron shall not exceed 2,000 pounds per square inch in tension nor 10,000 pounds per square inch in compression.

The unit pressures on the projected area of the bottom bearings of the guide vanes of the turbine shall not exceed 2,000 pounds per square inch, and on runner-blade bearings shall not exceed 2,800 pounds per square inch.

SEC. 17. *Turbine operating requirements.*—Each turbine shall operate at any gate opening, under any head between 58 and 75 feet, inclusive, and at any power output within the limits of capacity guaranteed by the contractor, without causing objectionable surges in power output, detrimental vibrations, or objectionable noises other than those due to the resonance of the power plant substructure.

All parts of the turbines shall be designed and constructed to withstand without injury, for not less than 1 hour, any stress and wear caused by the maximum runway speed under the approximate maximum operating head of 70 feet.

The Authority will use every reasonable precaution to limit the output of the turbines to the maximum loads specified and guaranteed by the contractor; however, the turbines shall be so designed and constructed that a temporary overload equal to that produced by a combination of maximum operating head of 72.5 feet and full gate opening shall cause no damage. In making provision for such an overload, the unit stresses in the parts may be increased as specified in section 16.

SEC. 18. *Cavitation.*—The runners and the discharge rings of the turbines shall be free from excessive cavitation, or pitting, for a period of not less than 1 year after the turbine is placed in commercial operation, provided that the turbine shall not be operated at less than one-quarter of its rated capacity for more than 876 hours during the year, and provided further that the total number of hours of operation of a turbine at outputs greater than those stipu-

lated by the contractor in his cavitation guarantee under corresponding conditions of headwater and of tailwater level shall not exceed 50 hours during the year. If, within the 1-year period after being placed in commercial operation and under the above operating conditions, a turbine runner or throat ring is pitted so that over any continuous surface area of 4 square inches or more the metal is reduced in mean thickness by three-sixteenth inch or more, the contractor shall repair all pitted places in a satisfactory manner by welding with stainless steel. For this purpose, the Authority will unwater the unit, provide the necessary platforms, compressed air, welding machines, and electric power; and the contractor shall furnish all other necessary tools, materials, and labor.

Excessive cavitation, or pitting, shall be defined as the removal of metal from a runner aggregating 300 cubic inches or more, or the removal of metal from a discharge ring aggregating 200 cubic inches or more. In case of excessive cavitation, the Authority may require the replacement of the defective parts.

Damage resulting from the chemical composition of the water shall not be considered as "cavitation" or "pitting" within the meaning of the words as used in this specification.

In case of delay, through no fault of the contractor in placing a turbine in commercial operation, the period of the cavitation guarantees shall terminate not later than 30 months from the date of final shipment of that turbine.

SEC. 19. *Turbine runners.*—Each adjustable blade runner shall consist of a cast-steel hub with separate cast-steel blades mounted therein and with the necessary mechanism for adjusting the blades housed within the hub.

The design of the hubs, blades, and mechanism shall be such that individual blades and their connections may be readily removed from the hub. All parts shall be of rugged construction and adequately connected to prevent excessive vibrations or deflections. The rod which operates the mechanism shall be provided with bronze-bushed guide bearings above and below the blade-adjusting yoke. The runner-blade bearings and link bearings shall be fitted with removable bronze bushings of suitable composition. At the option of the contractor, roller bearings may be used inside the runner hub. The hubs shall be designed to be filled with lubricant and with the runner assembly shall be oiltight.

The bottom flange of each hub shall be sufficient to support the weight of the runner, the shaft, and the inner head cover assembly, in a temporary support during erection.

Provision shall be made for the proper lubrication of all bearings within each runner hub, and adequate seals shall be provided for each runner-blade stem to retain the lubricant in the hub and prevent the entrance of water. At the seal each stem shall be provided with a suitable noncorrodible metal sleeve secured to the stem. Convenient means shall be provided for draining the lubricant from the hub, for adding lubricant from a point in the turbine pit, and for draining any water from within the hub to a point in the pit.

Stainless steel of a minimum finished thickness of one-eighth inch and of not less than two layers of welded metal shall be securely welded to the under surface of each blade where most subject to cavitation. The total area so covered on each runner shall be not less than 50 square feet. The location of these areas shall be approved by the engineer after the efficiency and cavitation tests of the model have been made. The outer edge of each blade shall be protected by covering the edge with a strip of stainless steel not less than one-half inch thick, securely welded and doweled to the blade.

All surfaces of the runners exposed to the flow of water shall be finished smooth by grinding or by other means and shall be free from hollows, depressions, abrupt changes, cracks, or projections, which might cause local cavitation. The lower flange of each turbine shaft shall be securely bolted to the top of its hub in such manner that they can be readily dismantled.

A cone attached to the bottom flange of each hub and extending below the bottom of the runner blades shall be provided to guide the water as it leaves the runner. The cone shall be divided into an upper and lower part with flanged connection. The upper part shall be sufficient to support on its lower flange the shaft, the runner, and the inner head cover assembly on a temporary support, during erection, and the upper part shall be oiltight to retain the lubricant in the hub.

The entire runner shall be carefully balanced before leaving the contractor's shop. He shall furnish the necessary temporary support for the runner

hub for convenient erection of the complete runner, shaft, and inner head cover assembly, in the field.

SEC. 20. *Turbine shafts and cylinder covers.*—Each shaft and each cylinder cover respectively shall be an open-hearth, carbon or alloy integral steel forging, heat-treated as necessary, smooth finish machined all over and hollow-bored not less than 9 inches in diameter throughout its length. The bore shall be smooth-finished to facilitate inspection of the metal in the interior of the shaft.

Each shaft shall be provided with removable sleeves where passing through the stuffing box in the head cover and through the guide bearing. These sleeves shall be made of corrosion-resisting steel, accurately machined, polished, and secured to the shaft. A forged collar shall be provided on the shaft, such that the shaft and runner may be supported on the head cover when the shaft is uncoupled from the generator shaft.

The lower end of each shaft shall be provided with a flange which with the complementary flange on the runner hub shall form the coupling between runner and shaft. The upper end of each shaft shall form the operating cylinder of the servomotor for adjusting the runner blades. The upper end of the operating cylinder shall be provided with a flange for bolting to the lower flange of the cylinder cover. The top flange of this cover with the complementary flange of the generator shaft shall form the coupling between the two shafts.

The contractor shall design in cooperation with the generator manufacturer the entire coupling between his work and the generator shaft, but the generator manufacturer will furnish the generator half-couplings and the coupling bolts.

Both the upper and lower couplings shall be of the male and female type with a suitable fit between the tongue of the male half and the socket of the female half of the coupling.

All coupling bolts shall be fitted and of suitable material and dimensions consistent with the design of the coupling. Taper bolts shall not be used.

The couplings between the turbine shafts and the generator shafts are to be finished and fitted by the generator manufacturer, and the contractor under item 1 shall at his expense ship the turbine shafts to the generator manufacturer. When so shipped, the parts shall be completely fabricated, assembled, and inspected, except that the contractor shall only rough-drill the turbine half-couplings, if necessary, to a metal template which shall precede the shaft to the generator manufacturer for use in rough-drilling the generator half of the coupling. The template shall be furnished by the contractor. The generator manufacturer will connect together the turbine and generator shafts, check their alignments, make all necessary corrections, ream the holes in the flanges of both turbine and generator shafts, furnish the coupling bolts and nuts, and fit the bolts. After checking and fitting by the generator manufacturer, the parts will be shipped direct to destination at the expense of the generator manufacturer.

The contractor shall provide suitable casings or guards for the couplings of the turbine and generator shafts. These guards shall be of the stationary type.

Suitable means shall be provided with each shaft for adding lubricant to the runner hub and for draining any water from within the hub. The contractor shall also provide suitable means for the drainage of any oil leakage at each runner-blade servomotor and for removing such leakage from the turbine pit.

SEC. 21. *Servomotors for adjusting runner blades.*—The operating cylinder of the servomotor for adjusting the tilt of the blades of each runner shall be forged integrally with the turbine shaft, and shall be of adequate capacity to completely open or close the runner blades in 8 seconds with oil pressure of 250 pounds per square inch. The piston shall be of cast steel and the connecting rod of forged steel. The piston shall be provided with suitable removable piston rings ample to prevent excessive leakage.

Bronze-bushed guide bearings shall be provided for the piston rod, located between the operating cylinder and the runner, as necessary to prevent vibration or distortion. A suitable oil seal shall be provided for the piston rod, below the operating cylinder, to prevent excessive oil leakage from the cylinder, and provision shall be made for the drainage of any such leakage past the seal.

Sec. 22. *Oil supply heads.*—The contractor shall furnish the oil supply head for each turbine complete with restoring mechanism, all piping, valves, stuffing boxes, and other parts necessary for the transmission of the operating fluid between it and the runner operating cylinder. Provision shall be made so that any such pipes in each hollow generator shaft may be readily removed and replaced without dismantling the coupling between the turbine and generator shafts. Parts in contact, having relative motion, shall be bronze-bushed, and the oil supply pipes in the hollow generator shaft where passing through a stuffing box shall be provided with extensions of suitable metal properly machined and provided with means of lubrication. Provision shall be made to return any oil leakage to the governor sump tank. The head shall be mounted above the generator on a support furnished by the generator manufacturer. The contractor shall cooperate with the generator manufacturer to develop a proper arrangement of the supply head and connection to the generator. Provision shall be made for mounting above the supply head an auxiliary generator for operating the governor flyballs, which if installed will be furnished under item 2.

Two pressure gauges shall be provided for each turbine to show the pressure on opposite sides of the oil head. These gauges shall be mounted neatly and each shall be provided with a shut-off cock. An indicator shall be provided on the outside of the oil head to show the blade angle.

A float switch shall be provided at the drainage chamber to make contact in case of excessive oil leakage from the stuffing boxes.

Sec. 23. *Turbine guide bearing.*—The turbine shall be provided with an oil-lubricated guide bearing with suitable babbitt lining for the shaft. The bearing shall be located above the stuffing box with space to remove or replace the gland and packing. The runner, shaft, and bearing shall be arranged to permit at least three-eighth-inch vertical movement of the rotating parts of the turbine for adjusting and dismantling the unit thrust bearing. The guide bearing support or housing shall be of heavy construction, fastened in the head cover and designed to support the bearing shell rigidly. The bearing shell shall be split vertically to facilitate dismantling.

The bearing shall be accurately bored, suitably grooved for oil circulation, and scraped to proper fit on the shaft. Suitable lifting eyes and jackscrews shall be provided to facilitate removing and replacing the bearing.

Lubrication of the bearing shall be by oil, circulated through the bearing. Circulation shall be from the reservoir below the bearing through the oil pumps to the reservoir above the bearing, then by gravity through the bearing to the lower reservoir. If cooling of the oil is necessary, suitable cooling coils, through which cold water from the scroll case can be circulated, shall be provided in the oil reservoir, but cooling coils shall not be placed in the bearing housing. The lubricating system shall have sufficient capacity to supply an ample amount of oil to the bearing, and the lower oil reservoir shall be sufficient to hold all the oil in the entire system. The upper reservoir shall be connected to the lower reservoir by an overflow pipe, the size of which shall be sufficient to hold the oil level in the upper reservoir practically constant with one or two pumps operating.

Two independent approved electric-motor-driven positive displacement rotary oil pumps of the gear or screw type shall be provided for circulating the oil. The pumps shall be mounted in an alcove provided in the turbine pit liner or other convenient location. One oil pump shall be driven by a 3-ph., 60-cycle, 440-v. motor and the other by a 250-v. direct-current motor. The pump motors shall have weatherproof frames with enclosed conduit boxes, insulation impregnated against moisture and oil, and ball bearings in dust-proof housings, with adequate means of retaining the correct amount of lubricant without dripping. Capacity speed and torque of the motors shall be suitable for the pump requirements. Motors shall be designed for full-voltage starting and shall conform to NEMA and AIEE Standards.

Normally the oil shall be circulated by the alternating-current motor-driven pump, and the direct-current motor-driven pump shall be arranged to start automatically and supply oil to the bearing upon failure of the alternating-current motor-driven pump to supply sufficient oil to the bearing. Two float switches, each having two independent 250-v. direct-current contacts, shall be provided—one contact on float A for shutting down the unit when the oil level in the upper reservoir reaches a predetermined low level position, the other contact on float A for preventing the starting of the unit until the oil level in the upper reservoir has reached a predetermined normal level posi-

tion. One contact on float B for starting the direct-current motor-driven pump when the oil level in the upper reservoir reaches a predetermined low level position and the other contact on float B for shutting down the direct-current motor-driven pump when the oil level in the upper reservoir reaches a predetermined normal level position. A contactor for the direct-current oil pump motor shall be provided; it shall be three-pole and shall have four auxiliary switches. The contactor shall have an enclosed rating of not less than 45 amp. An oil flow indicator shall be provided. It shall have one 250-v. direct-current contact for connection to an alarm provided by the Authority. A bearing thermal relay shall be provided for mounting in the turbine pit. It shall be of the manual-reset type for emergency shutdown. Wiring to the governor shut-down mechanism shall be provided by the Authority. A manually operated control switch for each pump motor with indicating lights shall be furnished by the contractor under item 2 for mounting on the governor cabinet. Local control switches for mounting inside the turbine pit will be supplied by the Authority. Each pump shall be supplied with a pressure gauge, which shall be mounted on the equipment or at some convenient point inside the turbine pit.

The contractor, under item 1, shall furnish two suitable remote indicating mercury-type thermometers with 250-v. contacts—one for alarm and one for shut-down, located in the babbitted surface of the bearing shell. The indicators shall be located on the governor cabinet and shall be mounted by the contractor under item 2.

The contractor, under item 1, shall provide two temperature detectors in the guide bearing shell and one in the lower oil reservoir. The temperature detectors shall be of the resistance type, 10 ohms at 25° C., 250 v., AIEE standard, and will be connected to the micromax temperature recorder furnished by the contractor, under item 2, mounted on the governor cabinet.

Two independent, approved electric-motor-driven sump pumps shall be provided for removing water from the head cover barrel. The pumps shall be mounted in the head cover barrel adjacent to the bearing and shall be capable of removing all leakage water which might accumulate in the pit. One pump shall be driven by a 3-ph., 60-cycle, 440-v. motor and the other by a 250-v. direct-current motor. The pump motors shall have weatherproof frames with enclosed conduit boxes, insulation impregnated against moisture and oil, and ball bearings in dustproof housing, with adequate means of retaining the correct amount of lubricant without dripping. Capacity speed and torque of the motors shall be suitable for the pump requirements. Motors shall be designed for full-voltage starting and shall conform to NEMA and AIEE Standards.

Normally, the alternating-current motor-driven pump shall be used for unwatering the sump; in case of inability of this pump to hold the water to a predetermined level, the direct-current motor-driven pump shall automatically start. Each pump shall be float-actuated and shall be entirely automatic in its operation.

The contractor shall furnish the lubricating system for the bearing complete as specified and including sight-flow indicator, pressure gauges, piping, oil level indicator for the oil reservoir, and all necessary switches, relays, and other accessories for the safe and automatic operation of the system. All piping, valves, and fittings shall be of brass. All wiring for power supply to the motors, alarms, and protective apparatus will be furnished by the Authority. The design and construction shall be such that under any operating conditions of the turbine, no water shall enter the guide bearing lubricating system, and there shall be no appreciable leakage of oil past the lower oil shedder or by overflow from any part of the system.

At the option of the contractor a grease-lubricated bearing may be furnished. If a grease-lubricated bearing is furnished it shall be designed to fit into the lower portion of the head cover barrel with a watertight stuffing box above. It shall be arranged so that grease entering at the top of the bearing shall waste to tailwater at the lower end of the bearing. The arrangement shall be such that a minimum amount of grease will be wasted.

The bearing shall be equipped with a minimum of two grease connections located near the top of the shell. Grease for the bearing shall be Keystone "Velox No. 3" and shall be furnished by the automatic greasing equipment specified in section 29.

The contractor under item 1 shall furnish, with the grease-lubricated bearing, two suitable remote indicating mercury-type thermometers, two resistance-

type temperature detectors, and two sump pumps as outlined above for use with an oil-lubricated bearing.

All items and conditions listed under the oil-lubricated bearing above shall apply to the grease-lubricated bearing where applicable.

SEC. 24. *Turbine speed rings.*—The speed ring for each turbine supporting the upper parts shall be designed to withstand all stresses to which it may be subjected during operation and dismantling, and during installation when braced with suitable temporary supports, including those occasioned by the weight of substructure masonry, of the generator, and of the turbine, and by hydraulic thrust and water pressure.

The ring shall be made of steel castings or of steel plates welded and shall consist of upper and lower flanges connected by integral columns. Flanges shall be provided for connections between the ring and the pit liner, head cover, bottom plate, and discharge ring. Provision shall be made to attach concrete reinforcing bars to the upper and lower flanges. The baffle vane in the speed ring shall extend to the outer diameter of the speed ring and shall be so designed as to provide an adequate connection to the concrete of the scroll case. The speed ring shall be sectionalized, with flanged and bolted joints between sections, to facilitate shipment and handling.

Piezometer connections not exceeding two in number shall be provided in the upper flange of each ring with bronze or stainless-steel plugs as located by the engineer.

Suitable jacks, jack pads, and anchor bolts shall be provided for leveling and supporting the speed ring in position while the concrete of the scroll case is placed. Grout holes shall be provided in the lower flange to facilitate placing concrete under the speed ring.

SEC. 25. *Turbine scroll cases.*—The turbine scroll cases will be constructed by the Authority in the concrete substructure. The contractor shall furnish detail designs which shall conform to the general layout shown on the Authority's drawings, and the scroll cases will be constructed accordingly.

The contractor shall provide a door frame and door for access from a passageway in the substructure to the interior of each scroll case. The clear opening for the door shall be 30 inches wide by 48 inches high. The door frame shall be of cast iron, ribbed, or rigid construction, designed for embedding in the concrete, and complete with anchor bolts. The frame for the door shall form a lining for the access tunnel for a distance of not less than 20 inches.

The door shall be hinged to swing into the scroll case and when closed shall be flush with the interior of the case. The door shall be of cast-iron or steel-plate construction, designed to withstand the pressure and to be tight under maximum headwater conditions. The door and its frame shall be machined on their sealing surfaces and provided with a sealing gasket. Hinge pins, bolts, jackscrews, and supporting washers for the door shall be of bronze. A test cock shall be provided to determine whether the water level is below the sill of the door.

SEC. 26. *Turbine head covers.*—Each head cover shall be made of steel castings or steel plates welded, and shall consist of an outer and an inner cover, both sectionalized to facilitate shipment, erection, and dismantling. The head cover shall be designed to support, and a suitable permanent support shall be provided under the collar on the shaft for the runner and shaft during erection or dismantling. The head cover shall be so designed that the inner cover, runner, guide bearing, and shaft may be installed or removed as a unit without dismantling the guide vane levers or removing the outer cover. Provision shall be made for the attachment of the two hooks of the gantry crane to the above assembly for handling. A manhole shall be provided in the head cover. Means shall be provided for the collection of any leakage of water above the head cover.

The design shall be such as to prevent the turbine runner from lifting the rotating parts off the thrust bearing of the generator under any conditions of operation, but provision shall be made that the runner and shaft may be raised not less than three-eighths inch to permit adjustment and dismantling of the generator thrust bearing.

A stuffing box for each gate or guide vane stem shall be provided in the head covers. All bolts and nuts used in connection with the stuffing box shall be bronze. The under side of the outer cover shall be machined and shall

have a suitable clearance over the guide vanes. Two bronze-lined guide bearings for each gate stem shall be provided in the head cover, one above and one below the stuffing box.

A check valve with dash pot, with means to close it manually and with the necessary piping, shall be provided for the admission of air from the turbine pit to the space below the head cover when the gates are nearing the closed position. The valve shall act as a check valve to prevent the outflow of air or water, and the opening shall be adjustable. The openings in the head covers for such admission of air shall be so located as to best obviate vibrations and disturbances in the turbine.

The necessary piping to outside the pit liner shall be provided for the admission of compressed air into the space below each head cover to depress the water in the draft tube if it is desired to motor the unit.

SEC. 27. *Turbine bottom plates or lower guide vane rings.*—A suitable bottom plate or lower guide vane ring shall be provided for each turbine, of steel castings or welded steel plates, sectionalized. It shall be designed to be bolted to and to be removable from the discharge ring. A bronze-lined guide bearing shall be provided in the ring for the lower stem of each guide vane.

SEC. 28. *Turbine discharge rings.*—The discharge ring for each turbine shall be made up of steel plates welded, sectionalized, designed to be permanently set in concrete, and heavily ribbed to secure anchorage to the concrete and to prevent distortion. It shall be securely bolted to the lower flange of the speed ring and shall extend 12 inches below the lower edge of the runner blades when they are in the steep position.

The lower end of the discharge ring shall have an extension for connection to the draft tube liner. The holes in this extension will be drilled in the field by the Authority.

That part of the discharge ring below the center line of the runner shall have a spherical shape to make the clearance, when the tilt of the runner blades is changed, a minimum suitable for proper operation. The inside surface of the ring shall be machined to a smooth finish.

The upper face of the discharge ring shall form a seat on to which the bottom plate or lower guide vane ring shall be securely bolted.

SEC. 29. *Guide vanes and operating mechanism.*—Each guide vane and its stems shall be an integral steel casting. The contacting surfaces of gates and the gate stems shall be machine-finished, and the surfaces of the gates shall be ground smooth. Each gate shall be provided with 3 bronze-bushed greased-lubricated guide bearings, 1 in the bottom ring and 2 in the head cover (one below and the other above the stuffing box). The gate stems, where passing through the two bearings adjacent to the water passages and through the stuffing boxes in the head cover, shall be protected with suitable noncorrodible metal sleeves, shrunk onto the stems. Each gate stem shall be provided with a suitable thrust bearing above the stuffing box, arranged to resist the thrust in either direction and adjustable to support the gate in position and midway between the bottom ring and the head cover. All gates shall be interchangeable.

The grease piping leading to the bottom wicket gate bearing shall be three-eighths inch and of noncorrodible metal. The grease connection shall be made to the upper end of the pipe by means of an antifriction-type swivel. The entire grease piping and connections to the bottom bearings of each gate shall be tested in the shop under a pressure of 4000 p.s.i.

Check valves shall be provided between the bearings and the grease fitting where the bearings are subject to water pressure.

An automatic pressure greasing system shall be provided to lubricate each part of the gate mechanism having relative motion in contact. The system shall be designed so that it will deliver a measured quantity of Velox No. 3 grease to each bearing. No measuring valve shall contain either check valves or springs in its design.

The central pumping station shall be self-contained and equipped with a grease pump with positive mechanically driven valving. The grease pump may be operated by air or electric motor. Air-operated pumps shall be suitable for use with compressed air at 80 to 120 p.s.i. Electric motors shall be suitable for use with single-phase, 60-cycle, 115-v. current. The grease pump-

ing mechanism shall be arranged so that a standard commercial grease drum of 400-pound capacity may be used as the grease reservoir.

The system shall be provided with an adjustable timing mechanism suitable for operation with single-phase, 60-cycle, 115-v. current. This timing mechanism shall cause the system to gease each bearing at least once every 24 hours. The volume of grease applied to each bearing which is subjected to water pressure shall be sufficient when using the minimum setting of the adjustable timer to completely fill the clearance between the bearing surfaces once every 48 hours. The volume of grease applied to the bearings not subjected to water pressure shall be sufficient, when using the minimum setting of the adjustable timer, to completely fill the clearance between the bearing surfaces once every 96 hours, except the bearings under the gate ring, for which the volume shall be two-thirds less for each unit area of bearing surface. The volume of grease required to fill the space between bearing surfaces shall be determined on the basis of 0.002-inch clearance plus 0.001-inch increase in clearance for each 1-inch increase in diameter of the bearing.

If a grease-lubricated turbine guide bearing is offered under section 23 the motor and timer specified above shall be suitable for operation with 250-v. direct current instead of 115-v. alternating current. In addition, the greasing system shall be equipped with a separate d.c. timer, separate grease lines, and a transfer valve which will function to grease the turbine guide bearing independently of the wicket gate mechanism. The timer shall be adjustable from 1 minute to 1 hour. The entire greasing system shall be driven by a single d.c. motor. The arrangement shall be such that when a greasing cycle of the wicket gates has been completed the timers and transfer valve will automatically connect the pump to the system for greasing the turbine guide bearing. The arrangement shall be such that the transfer back and forth between the wicket gate system and the turbine guide bearing system will be positive and automatic and that the turbine guide bearing system will be in operation at all times except the actual period required for greasing the wicket gates.

All piping and hose between the pump and point of lubrication shall be arranged as inconspicuously as possible, and the arrangement shall be such that the minimum number of connections need be broken when dismantling the turbine.

The gate-operating mechanism shall be of ample strength to withstand the maximum load that can be imposed upon it under any operating condition. The entire mechanism shall be of the outside type and so mounted within the turbine pit as to be readily accessible for inspection, adjustment, or repair. The gate-shifting ring shall be a steel casting or of welded steel-plate construction, of rigid construction, and provided with renewable bronze guides.

Sec. 30. *Turbine servomotors.*—Each turbine shall be equipped with two oil-pressure-operated double-acting hydraulic cylinders, or servomotors, the capacity of which shall be sufficient to operate the gates when supplied with oil at a minimum pressure of 250 pounds per square inch. With an adequate supply of oil at the minimum pressure, the two servomotors shall be capable, under maximum head conditions, of moving the turbine gates a full opening or a full closing stroke in 8 seconds.

The servomotors shall be so designed and constructed that the work of moving the gates shall be divided approximately equally between the two cylinders and the forces applied in approximately equal magnitude on opposite sides of the gate shifting ring.

The cylinders shall be accurately bored, provided with flanges for the connection of piping, and with long stuffing boxes to prevent oil leakage along the piston rods. Pistons shall be of cast steel, or cast iron, each fitted with not less than three cast-iron piston rings shaped to give close contact and uniform pressure on the cylinder walls and to prevent oil leakage past the pistons. The necessary piping and restoring cable to connect to the governor with supports and suitable sheaves and protection for the restoring cable shall be furnished by the contractor under item 2. The contractor under item 1 shall provide a suitable connection on a servomotor piston rod, for the restoring cable.

The servomotors shall be equipped with adjustable means by which the rate of closing may be sufficiently retarded between the speed-no-load position for

maximum head and the fully closed position to prevent shock to the guide vane operating mechanism when the vane surfaces contact.

Suitable mechanical locking devices shall be provided for each turbine so that the turbine guide vanes may be held in the open or in the closed position against maximum governor oil pressure in the servomotors. Such devices shall be designed for convenient use, and shall be of the screw type operated by a handwheel, or equal. They shall be permanently mounted on the outboard bearing or cross-head guide.

One servomotor assembly on each turbine shall be arranged for mounting a turbine wicket gate lock to be furnished by the contractor under item 2.

The cylinders of the servomotors shall be provided with machined mounting pads and mounted on corresponding pads on either the pit liners or the head covers.

An outboard bearing or cross-head guide shall be provided beyond the stuffing box of each cylinder to support the piston rod. Provision shall be made for collection and disposal of any oil leakage past the stuffing boxes.

A suitable adjustable mechanical blocking device shall be provided on one servomotor piston rod of each turbine to positively limit the maximum turbine output during periods of high head, and it shall be of sufficient strength to withstand the maximum force of the servomotors. This block shall be readily adjustable for different gate openings to suit different heads. It shall be of the screw type operated by a handwheel, or equal, and shall be mounted on the outboard bearing or cross-head guide.

Each servomotor shall be tested in the shop with warm oil or kerosene, at a pressure of 450 pounds per square inch, and shall be oiltight.

SEC. 31. *Turbine pit liners.*—A pit liner shall be provided for each turbine, composed of a lower and an upper part. The lower part shall be made of steel castings or steel plates of ample thickness, heavily ribbed, and shall extend from the speed ring to above the servomotors. Suitable openings shall be provided in the pit liner for convenient access, for ventilation, and for piping connections as required. The upper part shall be made of not less than one-half-inch steel plates, and shall extend upward from the top of the lower part toward the generator foundations. The internal diameter of the entire pit liner shall be such as to permit the removal of the inner head cover as a unit.

The lower part of the liner shall be made in sections with flanged connections, and shall be bolted and doweled to the top flange on the speed ring. Its internal diameter and height shall be sufficient to allow lifting the outer head cover clear of the guide vane stems sufficient to permit the removal of a guide vane without disconnecting the sections of the cover.

Provision shall be made to anchor the lower part of the liner to the concrete, and its diameter shall be such as to transmit to the speed ring, without eccentric loading, the load from the roof of the scroll case and the generator. Provision also shall be made to withstand the reactions of the servomotors in the pit liner or in the concrete backing. A drain consisting of perforated pipe or channels shall be welded to the outside of the liner near its top to intercept any moisture seeping up between the concrete and the liner, and drain connections shall be provided to dispose of such leakage.

SEC. 32. *Turbine draft tubes.*—The turbine draft tubes will be constructed by the Authority in the concrete substructure in accordance with detailed designs prepared by the contractor but conforming in general to the design shown on the Authority's drawings.

The contractor shall furnish for each turbine a draft tube liner of steel plates with welded or riveted joints. The entire interior of the liner shall be smooth and shall have no abrupt changes in direction. The number and design of sections of the liner shall be such as to reduce to a minimum the number of field joints. The joint between the draft tube liner and the discharge ring shall be riveted or welded and will be made by the Authority in the field.

The liner plates shall be three-quarter-inch thick, heavily reinforced on the outside with ribs of structural steel shapes having a flange to be embedded in the concrete. Provision shall be made for adequate anchorage to the surrounding concrete. Suitable jacks and anchor bolts shall be provided by the contractor to support the sections during erection and to support the liner while being concreted in place.

A door frame and watertight door not less than 24 inches wide by 36 inches high, in the clear, shall be provided in the liner and so located as to give access from a passageway in the substructure to the under side of the runner. The door frame shall be securely fastened to the draft tube liner. The interior surface of the door shall be flush with the interior of the liner; the door shall have bronze hinge pins, bronze bolts, bronze jackscrews, bronze supporting washer, and shall swing outward from the draft tube.

A test cock or other means shall be provided to determine whether the water level in the draft tube is below the sill of the door.

SEC. 33. *Turbine drains.*—Adequate provision shall be made for the collection of any water leakage from the head cover, the stuffing box, and other parts of each turbine subject to leakage and for its delivery to a point outside the pit liner or the speed ring for disposal by piping provided by the Authority.

SEC. 34. *Stairways, platforms, ladders, wrenches, and tools.*—The contractor shall furnish complete working, operating, and inspection platforms with stairs, handrailings, floor plates, and gratings in the turbine pit. All this equipment shall be designed for easy removal so that the turbine may be dismantled from above. Generator inspection platforms are specified separately and are not included in item 1.

The contractor shall furnish one complete set of case-hardened wrenches, special tools, special lifting tackle, and equipment necessary for the erection and dismantling of all parts of the turbine. The wrenches and tools shall be mounted on a neat plate-steel wrench board with marking to identify each tool.

ITEM 2. GOVERNING SYSTEMS

SEC. 35. *Description.*—The contractor under item 2 shall design, furnish, and deliver two complete oil-pressure governing systems for controlling the speed of the turbines. The governing systems shall be of the relay valve "actuator" type with motor-driven governor heads, complete with auxiliary control mechanisms, restoring mechanisms, oil-pressure systems, instruments, gauges, and accessory equipment and supports, as hereinafter specified and necessary for two complete governing systems.

The essential governing mechanism for the two turbines shall be mounted in a twin cabinet with the hand controls and certain instruments and gauges on its face. The cabinet shall be located on the operating floor with the front facing toward the operating aisle, probably on the downstream side of the generator.

The governors shall be designed to control the units when operating under the hydraulic conditions described in section 15, "Operating Heads."

Since the units will be of the automatic type and controlled from another station, the governors shall be provided with such automatic devices as necessary to be operated by the remote-control system selected.

This automatic equipment shall include necessary starting solenoids, timing devices, automatic governor brakes, automatic shut-down devices, automatic turbine gate locking devices, and automatic shut-off valves.

The main valves shall be provided with adjustable stops which can be set and locked so as to limit the opening of the valves and thus control the rate of motion of the wicket gates.

The pressure tanks for the governors shall be located on the floor directly behind the governor cabinet.

SEC. 36. *Capacity of each governing system.*—The governing system for each turbine shall be designed for operation with oil pressure varying from a maximum of 300 p.s.i. to a minimum of 250 p.s.i. The system shall govern the speed of the turbine under fluctuating commercial load conditions within the limits of regulation and within the degree of sensitivity guaranteed by the contractor, and, with the unit supplying a separate load, it shall operate without causing hunting of the turbine gates and without causing changes or swings to the load.

With oil pressure of 250 p.s.i., the governing system shall be adequate to operate the gate servomotors of the turbine through a full stroke, either opening or closing in 4 seconds.

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The system shall include equipment of relative capacities not less than the following:

Each oil pump, ratio, of capacity (g.p.m.) to volume (gallons) of its gate servomotors and runner-blade operating cylinder	1.35
Each pressure tank, ratio of volume (gallons) to volume (gallons) of its gate servomotors and runner-blade operating cylinder	13
Each sump tank, ratio of volume (gallons) to volume of its pressure tank (gallons)	0.5
Each oil pump, ratio of capacity (g.p.m.) to volume (gallons) of its gate servomotors	2.5
Each pressure tank, ratio of volume (gallons) to volume (gallons) of its gate servomotors	20

Governing mechanism

SEC. 37. *Governor actuator.*—The component parts of each actuator shall be mounted on top of the sump tank.

The actuators shall be enclosed in a cabinet of rigid construction. The operating handles or wheels, gauges, and instruments shall be mounted on the face of the cabinet, arranged as specified in section 62. The cabinet shall be properly ventilated and shall be dustproof.

The equipment within the cabinet shall be readily accessible for adjustment or for replacement of parts, and adequate doors shall be provided in the cabinet for access.

Positive control of the time of opening or closing the turbine gates shall be provided. This control shall be adjustable so that the time of opening or closing may be varied between 4 and 12 seconds for full stroke. The control shall be such that no action of the flyball control, control solenoids, load limit, or other devices can cause a gate movement faster than that for which the control is set. The gate servomotors will have a throttling device to slow down the movement of the gates as they approach the closed position.

Provision shall be made for the application of automatic synchronizing and of automatic load and frequency control, such as manufactured by the General Electric Co. or Leeds & Northrup Co.

The equipment of the actuator shall include the parts specified in the following sections 38 to 53, inclusive.

SEC. 38. *Governor head.*—The speed-responsive element of each governing mechanism shall be a set of flyballs driven by a direct-connected a.c. motor, assembled as a unit with the other governing mechanism in the cabinet. The speed of the flyballs shall vary in direct proportion with the speed of the main generator shaft and shall not be affected by ordinary variations in voltage or current of the main generator or of its exciters. The source of power for driving the flyball motor shall be either an independent self-exciting alternating-current generator or potential transformers connected to the main generator terminals.

If the source of power for driving the flyball motor is an independent self-exciting a.c. generator, it shall be furnished complete and arranged for mounting above, and shall be direct-coupled through a suitable flexible coupling to the shaft to the main generator. The connection shall be such that in combination with the electric tachometer an indication will be given when the turbine starts to rotate and just prior to its coming to a dead stop. This flyball generator shall be completely enclosed in a suitable housing with the overspeed and tachometer devices and shall be carefully insulated from the main turbine and generator to prevent stray currents.

The contractor shall cooperate with the generator manufacturer to design a proper arrangement for mounting the flyball generator and for its connection to the shaft.

If the source of power for driving the flyballs is potential transformers connected to the generator terminals, the contractor shall supply these transformers and fuse blocks. They shall be General Electric potential transformers type JE, or equal, and General Electric fuse blocks type ES–1, or equal, with a standard voltage ratio of 13,800 to 115.

The contractor shall furnish complete information and data regarding these transformers and connection. With the potential transformer drive, the contractor shall furnish 3-ph., low-voltage relays and such protective devices as may be required in connection with this type of flyball drive.

SEC. 39. *Gate- or load-limit device.*—This device shall be manually operated at the actuator and electrically operated by a split-field motor controlled from the switchboard and shall include two indicators of the duplex type, each showing both gate-opening and load-limit setting. One indicator shall be furnished and mounted by the contractor on the cabinet. The other shall be furnished by the contractor and will be mounted by the Authority on the switchboard. The indicator mounted on the cabinet shall be equipped with two potentiometers for operating the remote indicators, one for the gate opening and one for the load-limit setting. The potentiometers will serve also for telemetering. A control switch for the splitfield motor will be provided on the switchboard by the Authority.

SEC. 40. *Synchronizing or speed-level device.*—This device shall be manually operated at the actuator and electrically operated by a split-field motor controlled from the switchboard. Two indicators shall be furnished and one shall be mounted on the cabinet by the contractor; the other shall be mounted on the switchboard by the Authority. The indicator mounted on the cabinet shall be equipped with a potentiometer for operating the indicator on the switchboard. The potentiometer may also be used for telemetering. The speed-level control shall function to adjust the speed of the turbine from 85 percent of rated speed to no load and zero speed droop, to 105 percent of rated speed at full load and maximum speed droop.

The design of this device shall be such that when the turbine is operating at rated head, one electrical impulse of 1-second duration from the controller to the split-field motor will produce a gate movement equivalent to approximately 1,000 kw. The manual control shall be so arranged that a gate movement equivalent to approximately 2,000 kw. is obtained for each revolution of the control knob or handwheel.

A control switch for the split-field motor will be provided on the switchboard by the Authority.

SEC. 41. *Automatic shut-down.*—The automatic shut-down device shall operate in response to the various protective devices and to emergency switches, at the actuator and at the main switchboard, to shut down the turbine. The automatic device shall also provide for closing the turbine gates to the speed-no-load position in response to the overspeed switch and shall reset automatically upon restoration of the overspeed switch to its normal position. At the option of the contractor a separate speed-no-load device may be provided.

The devices shall function through the deenergizing of one or more normally energized solenoids operated by 250-v. d.c. circuits.

A shut-down and reset switch shall be provided on the cabinet, and when the unit has been shut down by this means resetting shall be possible only by restoring the switch to the "normal" position.

SEC. 42. *Automatic wicket gate lock.*—The automatic turbine wicket gate lock shall operate to hold the wicket gates in the closed position upon loss of normal governor oil pressure or upon loss of station service power supply. It shall be designed in cooperation with the turbine manufacturer and shall be mounted on one of the turbine servomotors. Normally, the device shall operate through a complete closing and opening cycle each time the turbine gates are closed and opened due to operation of the shut-down solenoid. It shall be of rugged construction of sufficient size and strength to withstand any stresses to which it might be subjected.

SEC. 43. *Electric tachometer.*—The electric tachometer shall be suitably driven from the main shaft of the generator and insulated against stray currents. Two suitable indicating instruments shall be furnished. One shall be mounted by the contractor on the cabinet, and one shall be mounted on the switchboard by the Authority.

SEC. 44. *Overspeed device.*—The overspeed device shall be suitably driven from the main shaft of the generator and shall function to shut down the turbine to speed-no-load and to sound an alarm at a predetermined overspeed, resetting automatically at 105 percent of normal speed. It shall be insulated to prevent short circuits and shall operate through three single-pole, 3-amp., 250-v., d.c., ungrounded switches, changeable from circuit opening to circuit closing, one in the turbine shut-down circuit, one in the unit shut-down circuit,

and one in the alarm circuit. The Authority will provide the alarm. The overspeed device shall be insulated to prevent stray currents.

SEC. 45. *Speed droop adjustment.*—The device shall be designed for remote control from the main switchboard and for manual adjustment at the actuator. It shall be equipped with two indicators showing the percentage of droop employed. One indicator shall be mounted on the actuator by the contractor. The other will be mounted on the switchboard by the Authority. The device mounted on the actuator shall be equipped with potentiometer for operating the indicator on the switchboard. The range of adjustment of the speed droop device shall be from zero to 6 percent droop from zero to full gate opening, respectively.

SEC. 46. *Auxiliary switches.*—Two 5-pole, 3-amp., 250-v. d.c. switches, ungrounded, shall be furnished and shall function to close or open each pole at any desired gate opening. Each pole shall be electrically separate and adjustable as to make and break and as to position.

A single-pole switch shall be provided to open the "raise" circuit of the split-field motor of the synchronizing device when the gate-position indicator comes up to the setting of the load-limit device. Each switch shall be 3 amp., 250 v., d.c., ungrounded.

The gate-limit device shall operate a 5-pole auxiliary switch, 3-amp., 250-v., d.c., ungrounded. The operation of each switch shall be adjustable as to make and break and as to position.

SEC. 47. *Manual control.*—Means shall be provided at the actuator for manual control of the turbine gates using the oil pressure system. A convenient change-over device shall be provided to switch from governor to manual control and also to shut off the oil pressure. An indicator shall be furnished and mounted on the cabinet to show which control is engaged.

SEC. 48. *Generator air-brake control.*—An automatic brake-control mechanism shall be provided which will apply the brakes intermittently when the turbine is being shut down. This mechanism shall be adjustable as to delay before application and number of intermittent applications. In addition, a manual control switch shall be furnished for the generator air brakes. It shall be mounted on the governor cabinet and shall be manually operated without actuating the automatic device. For the unit there shall be provided two 250-v., single-pole pressure switches, one of which shall operate to sound an alarm (provided by the Authority) if the brakes should be applied when the turbine gates are open and the generator is connected to the line; the other shall operate to sound an alarm (also provided by the Authority) if the air pressure in the supply system is low. The control manual switch handle shall be pistol-grip type.

SEC. 49. *Air-brake gage.*—A gage of the duplex indicating type, graduated in pounds per square inch to indicate the air pressure on the supply system and also in the brake cylinders, shall be furnished and mounted on the cabinet.

SEC. 50. *Oil pressure gage.*—A pressure gage to indicate the pressure in pounds per square inch in the oil pressure tank shall be furnished and mounted on the cabinet.

SEC. 51. *Oil pressure switches.*—Three pressure switches shall be furnished, one for actuating the shut-down mechanism, one for starting the interlock circuit, and one for the alarm circuit when the oil pressure drops to a predetermined point. Each switch shall have one adjustable, 3-amp., 250-v., d.c., ungrounded contact.

SEC. 52. *Control valves.*—The contractor shall furnish the control valves for each turbine to control automatically the operating fluid to the runner operating cylinder. The valve shall be complete with cams, piping, stop valves, restoring rods or cables, and other connections between the valve and the oil supply head. The control valve shall be located in its governor cabinet, and proper provision shall be made for it. The restoring cable shall be enclosed in a suitable conduit, which shall be 2 inches in diameter where exposed near the kaplan head.

Cams shall be provided to suit the different heads under which the turbine is to operate. The design of the cams shall be perfected and fabrication completed after the turbine has been installed and placed in operation and the contractor has made such check tests as will enable him to perfect the design.

Provision shall be made so that the rate of movement of the runner blades can be adjusted between 4 seconds and 40 seconds, either for the full-opening stroke, or for the full-closing stroke.

To conserve the governor oil pressure for the use of the gate servomotors, an automatic device shall be provided to shut off the oil and stop the movement of the runner operating cylinder when the fluid pressure drops to a predetermined pressure and when the runner blades are more than one-half of full tilt.

A blade-angle indicator for each governor shall be furnished and mounted on the cabinet.

SEC. 53. *Wiring of actuator and cabinet.*—The contractor shall furnish and completely install all electrical wiring connecting the apparatus within and on the actuator and the cabinet, bringing all terminal connections to terminal blocks so located with the cabinet as to be readily accessible for making external connections in the field. All wiring shall be so located as to be conveniently accessible for maintenance and repair.

No wire shall be smaller than No. 12 Awg. All wires shall have 600-v., varnished cloth, asbestos, flameproof insulation. All terminal blocks shall be General Electric Co. type EB, or equal, and those for the annunciator shall provide approximately 24 terminals. Wiring diagrams for connections to the annunciator will be provided by the Authority.

Suitable lighting and light switches shall be provided for the interior of the cabinet.

Oil-supply systems for governors

SEC. 54. *Description of systems.*—The contractor shall furnish a complete oil system for supplying oil to operate each wicket gate and runner-blade servomotors. The twin system shall include two motor-driven pumps, two pressure tanks, sump tanks, and accessory parts, and all necessary piping.

The two oil pumps mounted in the twin cabinet shall be interconnected so that either pump can be used under normal operating conditions with the other pump shut down but automatically coming into operation if the oil pressure in the pressure tank falls to some predetermined point below that at which the first pump is set to start. The interconnection shall be provided with suitable stop valves and designed so that either pump can be dismantled while the other is operating.

Provision shall be made so that each of the two pumps can be operated by "start" and "stop" control, or the pump operated continuously, loading and unloading as demanded by the oil pressure requirements.

SEC. 55. *Governor oil pumps.*—The pumps shall be of the motor-driven, self-priming, positive-displacement type, each having a capacity against 300-pound pressure of not less than that specified.

Each motor shall be direct-connected to its pump and shall be of 440-v., 3-ph., 60-cycle, 40° C., squirrel-cage, low-starting current, induction type, designed for full-voltage starting and conforming to NEMA and AIEE Standards. Capacity, speed, and torque shall be suitable for the pump requirements. The motor shall have open frame, enclosed terminal box, insulation impregnated against moisture and oil, and ball or roller bearings in dustproof housings with adequate means of retaining the correct amount of lubricant.

An automatic control shall be furnished for each motor which will start the pump when the pressure in the pressure tank drops to a predetermined minimum and will stop the pump when the oil pressure rises to a predetermined maximum. This control shall be arranged so that the pump will reach full speed before it loads and will unload before the motor is disconnected from the power supply.

The oil pumps shall be mounted within the cabinet. Ventilation shall be provided, sufficient to carry away the heat occasioned by the operation of the pump motor, by means of filter-protected louvers in the cabinet.

The contactor or magnetic starting switch for the pump motors of the governor will be furnished by the Authority and mounted on the auxiliary unit board. The manual-control switch for the pump motors shall be furnished

by the contractor and shall be mounted on the cabinet. The individual pressure switches, furnished by the contractor, shall be for 460-v. a.c., and means shall be provided so that the operating range of the pump may be readily adjusted. Indicating lamps shall be provided and mounted on the face of the cabinet to show when the pump is operating or ready to operate.

SEC. 56. *Governor tanks.*—The contractor shall furnish a pressure tank of welded-steel construction equipped with a graduated oil-level sight glass having both manual and automatic shut-off cocks and guarded to prevent breakage, air blow-off valve, manhole, oil drain, suitable compressed air connection, and connections for the oil piping.

All connections, except for the blow-off valve, the compressed air connection, and the top connection of the gauge glass, shall be made below the oil level. Provision shall be made to prevent the oil level being lowered sufficiently to allow air to blow into the piping system.

The contractor shall furnish a sump tank of welded-steel construction, equipped with gauge glass, manhole, strainer through which all oil returning to the tanks shall pass, and connections for filling, emptying, or filtering.

The capacity of the pressure tank and of the sump tank shall be as specified in section 36. The pressure tank shall be constructed and tested in accordance with applicable paragraphs of the ASME Boiler Construction Code, for Unfired Pressure Vessels.

SEC. 57. *Governor piping.*—The contractor shall furnish all unloading valves, check valves, safety valves, and other types of valves, and all pipe and fittings for the connections between the pumps, pressure tank and sump tank, actuator, turbine servomotors, and any equipment furnished by him.

So far as practicable, all piping shall be assembled by the contractor before the governor is shipped. Oil piping shall be of such size that the maximum velocity of oil flow therein shall not exceed 18 feet per second.

The entire piping system shall be fusion-welded in accordance with the American Standards Association Code for Pressure Piping B31.1–42 and subsequent supplements, applicable paragraphs, except for such flanged joints and connections as may be necessary for erection or subsequent dismantling. So far as practicable, all welding shall be done in the shop.

Pipe shall be seamless steel tubing of size and thickness of wall required by the service and shall be scale free, and the interior surface shall be thoroughly cleaned by sandblasting or pickling. Flanged connections shall be made with welded Van Stone flanges, or equal.

Flanges and ends shall be properly protected for shipment.

Valves, except those built into or forming a part of a governor or pumping unit, shall be steel-body, bronze-mounted, extra-heavy solid-wedge type, with bronze rising stems. Bolts shall have semifinished heads and nuts, and finished washers if their location requires.

Long-radius pipe bends having smooth surfaces shall be used in place of fittings wherever practicable, and fittings if used shall be of the long-sweep type.

Switches, gages, and instruments

SEC. 58. *Accessories furnished and mounted by contractor.*—The contractor, under item 2, shall furnish and mount on the cabinet for the governor the following instruments and switches:

1—Annunciator reset switch.
1—Annunciator test switch.
1—Set of contact switches with indicating lights for the turbine bearing d.c. and a.c. oil pumps.
1—Switch for generator housing heaters.
1—Leeds and Northrup Micromax 12-point temperature recorder with two alarm contacts for use with 10 ohms at 25° C. resistance temperature detectors 0–150° C. range; 110-v., 60-cycle, synchronous motor drive, 10-inch chart with chart speed of 1¾ inches per hour. Temperature recorder to be mounted flush or semiflush.
1—Pressure gauge for indicating pressure on generator cooling water supply, scale 0 to 100 feet of water.

1—Three-pen Taylor mercury-actuated recording thermometer, or equal, with not more than 75 feet of temperature compensated tubing, scale 0° to 50° C. for generator cooling water inlet and discharge and thrust bearing discharge.
1—Synchronous clock, 8-inch dial, 115-v., 60-cycle motor.
1—Duplex pressure gauge to indicate penstock water pressure and scroll case water pressure, calibrated in feet of water, scale 0 to 300 feet.
1—Indicating and totalizing flowmeter of ring balance construction designed for full-scale deflection with a differential of 20 to 140 inches of water, to be connected to taps in the scroll case to measure the flow through the turbine, the calibration to be made after field tests.
1—Runner-blade angle indicator.
1—Emergency shut-down switch with red indicating lamp.
1—Control switch with three positions and indicating light to control the operating of the tailwater depressing system.
1—Control switch with lights for the emergency cooling water pump for the two units.
1—Control switch with lights for the 8-cubic-foot governor compressor.
1—Pressure gage to indicate the pressure in the air storage tanks, scale 0 to 200 psi.

The following instruments will be furnished by the generator manufacturer and shall be mounted on the cabinet by the contractor:

1—Guide bearing indicating thermometer with high-temperature alarm contact.
1—Thrust bearing indicating thermometer with high-temperature alarm contact.
1—Remote oil-level indicator for thrust bearing oil reservoir.

SEC. 59. *Accessories furnished by the Authority for cabinet mounting.*—The contractor, under item 2, shall mount on the governor cabinet the following accessory equipment to be furnished by the Authority:

1—Flush-mounted annunciator cabinet approximately 26 inches wide, 6½ inches high, and 8 inches deep.
1—Signal cabinet approximately 15 inches wide, 6½ inches high, and 11 inches deep.
1—Switch for control of carbon-dioxide fire-protection system.

One hand telephone set and one telephone jack will be furnished by the Authority and shall be mounted on the cabinet.

SEC. 60. *Accessories furnished by contractor for switchboard mounting.*—The contractor, under item 2, shall furnish the duplex gate opening and load-limit indicators specified in section 39 and the tachometer indicators specified in section 43, but the Authority will mount these instruments in the appropriate place on its switchboard.

SEC. 61. *Turbine gages.*—The contractor, under item 1, shall furnish for the turbine the following gages and devices, and the contractor, under item 2, shall mount the gages and indicators on the governor cabinet except as otherwise provided:

a. One combined pressure and vacuum gage, to indicate pressure or vacuum in the draft tube, to be mounted adjacent to the draft tube mandoor.

b. Two turbine guide bearing thermometers with high-temperature alarm contact.

The contractor, under item 1, shall furnish all piping and fittings between the gages and the turbine, including shut-off cocks at both gage and point of connection, and piping to the governor cabinet.

SEC. 62. *Type and arrangement of instruments.*—All instruments, gages, indicators, and control switches furnished by the contractor shall be of standard switchboard size, type, and finish. Before purchase, the contractor shall submit to the engineer for approval complete data covering them.

All control switches shall be Westinghouse Electric Corp. type W or General Electric Co. type SB, or equal. All indicating lamps shall be standard switchboard indicating lamps, with 1⅜-inch-diameter color caps and resistors. All equipment and wiring shall conform to the standards of the AIEE and NEMA.

The gages, instruments, and controls on the face of the cabinet shall be mounted on removable panels of the cabinet as directed by the engineer. Elec-

trical controls, switches, and instruments shall, insofar as possible, be mounted on swinging panels.

The various parts on the panel shall be arranged in a neat and orderly manner.

Each instrument shall be provided with a neat label indicating its purpose or use.

Each instrument shall be provided with antiglare glass as manufactured by the General Electric Co., or equal.

Each instrument shall be designed and arranged so that the glass may be removed without removing the instrument from the governor panel.

Motor-driven air compressor

SEC. 63. *Type and rating.*—The contractor, under item 2, shall furnish one air compressor of the motor-driven, 2-stage, 2-cylinder, air-cooled type, with air-cooled intercoolers and aftercoolers having a capacity of not less than 8 cubic feet of free air per minute (actual, not by displacement) against 300-pound gage pressure, complete with all piping, electrical connections, motor controls, and accessories. The compressor will be used for building up pressure in the oil pressure tank of the governor.

The compressor shall be equipped with an unloading device which will unload the compressor to atmosphere whenever the motor stops and maintain this condition until the motor is running at full speed. It shall also be equipped with a start-stop pressure control switch, a pressure relief valve, and a receiver pressure gage.

The motor and compressor shall be mounted with a pressure tank. This entire unit will be located outside of the actuator cabinet by the Authority. Suitable piping and valves will be provided by the Authority to connect the air compressor to the oil pressure tank.

The motor starter shall be of the magnetic type with thermal overload and undervoltage protection, operated by a push button located on or near the compressor assembly.

SEC. 64. *Motor.*—Motor shall be 440-v., 3-phase, 60-cycle, squirrel-cage, induction type, conforming to the AIEE and NEMA standards. It shall be sized for starting at rated voltage and for continuous operation at full load with a temperature rise not exceeding 50° C. Windings shall be impregnated to withstand moisture and braced to withstand starting stresses. The motor shall have ball bearings, splashproof frame, adjusting rails, and enclosed conduit terminals.

SHOP ASSEMBLY, CLEANING, AND PAINTING

SEC. 65. *Shop assembly.*—Before shipment, the parts of the equipment furnished under the contract shall be assembled in the contractor's shop as follows:

Each turbine

The runner and the shaft shall be fitted together, and the guide bearing and stuffing box fitted to the shaft.

The runner shall be completely assembled with its blade-operating mechanism. The runner blades shall be operated to demonstrate that they work freely and without excessive leakage.

The runner hub shall be tested to prove it is oiltight. Also the runner-blade operating cylinder, piston and piston rod, shall be assembled together and tested to prove the assembly free from excessive leakage.

The draft tube liner shall be completely assembled.

The lower pit liner, speed ring, and discharge ring, which are to be embedded in concrete, shall be assembled together.

The upper and lower pit liners shall be assembled together.

The head cover, bottom plate, guide bearing and housing, gates, gate-operating mechanism, and associated parts shall be assembled, together with the embedded parts if practicable. If it becomes necessary to ship the embedded parts before fabrication of all the other parts is complete, the outer head cover and bottom plate shall be fitted to their connecting embedded parts before the embedded parts are shipped. The head cover, bottom plate, guide vanes, and the remaining parts, except servomotors, floor plates, and pipes,

shall then be assembled together, with suitable temporary spacers or supports provided to hold the parts in their proper relative positions.

In shop assembly, all parts shall be carefully plumbed and leveled.

While assembled the parts shall be match-marked, and the upstream-downstream and the transverse center lines shall be accurately scribed on the horizontal flanges and center punch-marked on the sides for convenient erection in the field.

Connections between parts shall be shop-doweled, if practicable, or rough-drilled for field doweling.

Governor

The governor shall be completely assembled in the shop. The oil pumps shall be operated at specified capacity and pressure, and the governor head operated at rated speed.

The assembly of turbine and of governor will be inspected and checked by the engineer and all check measurements recorded for comparison with like measurements to be made in the field. Any errors, interferences, or faulty material or workmanship discovered by the engineer shall be promptly corrected by the contractor.

SEC. 66. *Shop cleaning and painting.*—After shop assembly and inspection, parts of the turbine and governor shall be cleaned and painted as follows.

All surfaces shall be cleaned of all loose scale, rust, dirt, oil, grease, or other foreign matter, employing such means as may be necessary to clean effectively without injuring the surfaces.

Surfaces to be in contact with concrete as identified on the contractor's drawings and a band 4 inches wide on either side of a field-welded joint shall not be painted.

Unfinished surfaces to be in contact with oil, except piping, shall be painted one coat of approved oilproof enamel. Other unfinished surfaces shall be painted with one coat of underwater grey paint, consisting of one prime coat and one finish coat.

Finished surfaces of parts made of ferrous metals shall be coated where practicable with white lead and tallow or other approved slushing compound.

The governor cabinet shall be coated with approved enamel of a color as directed by the engineer.

MATERIAL SPECIFICATIONS

SEC. 67. *Cast iron.*—Cast iron shall meet the requirements of the American Society for Testing Materials Standard Specification for Gray-Iron Castings for Valves, Flanges, and Pipe Fittings, designation A126–42, class B.

SEC. 68. *Steel castings.*—Steel castings shall be of quality equal to that required by the American Society for Testing Materials Standard Specification for Carbon-Steel Castings for Miscellaneous Industrial Uses, designation A27–46T, grade 65–35 or 70–36.

SEC. 69. *Steel plates.*—Steel plates, except as otherwise specified, shall conform to the American Society for Testing Materials Standard Specification of Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels, designation A285–49T, flange or firebox quality.

Rivets, except as otherwise specified, shall conform to the American Society for Testing Materials Standard Specification for Boiler Rivet Steel and Rivets, designation A31–49T, grade A.

SEC. 70. *Corrosion-resisting steel.*—Corrosion-resisting steel (sheet, strip, and plate) shall meet the requirements of the specification of the American Society for Testing Materials, designation A176–49, grade 4, type 430, except where the use of other allows may be approved for special purposes, and except that grade 2, type 410, may be used for wearing plates specified in section 30.

SEC. 71. *Bronze castings.*—Bronze castings shall be of a quality equal to that required by the specification of the American Society of Testing Materials, designation B143–49. Bronze bearing bushings shall be of a quality equal to that required by the specification of the American Society for Testing Materials, designation B22–49, alloy C.

SEC. 72. *Noncorrodible bolts and nuts.*—Bolts and nuts shall be made of stainless steel or bronze when used under the following conditions:

> Throughout the work when bolts or nuts, or both, are subject to frequent adjustment or removal, such as adjusting bolts for gland rings of stuffing box, manhole bolts, bolts on mandoors, removable screens, strainers, and adjustable bearings.

The materials shall have free-machining qualities and be suitable for heading in a bolt machine.

Bronze for bolts and nuts shall be of quality equal to that required by the American Society for Testing Materials Standard Specification for Naval Brass Rods, Bars, and Shapes, designation B21–49T, alloy A or B.

SEC. 73. *Welding.*—The design and procedure for welded joints and welded connections, the welding, and the fabrication of welded steel parts shall be approved and shall conform to the applicable paragraphs of the Boiler Construction Code of the American Society of Mechanical Engineers, section VIII for Unfired Pressure Vessels, 1950 edition.

TESTS

SEC. 74. *Turbine efficiency and cavitation.*—The turbine efficiency and the cavitation limits shall be determined by a series of tests of a scale model of the turbine and water passages which shall be made in an approved manner in accordance with the best engineering practice and witnessed by the engineer. The model shall be homologous with the turbine and its water passages, and the tests shall be made under homologous conditions corresponding to those for which guarantees have been made by the contractor.

Efficiency of the turbines shall be determined from the efficiency of the model corrected by the so-called Moody formula as follows:

$$\mathrm{Eff}_2 = 100 - (100 - \mathrm{Eff}_1) \times \left[\frac{D_1}{D_2}\right]^{1/4}$$

in which
D_2 = diameter of turbine runner
D_1 = diameter of model runner
Eff_2 = efficiency of turbine (percent)
Eff_1 = efficiency of model (percent)

The correction shall be applied to the point of maximum efficiency of the model. The efficiency (percent) of the turbines, at other points tested, shall be at model efficiency (percent) increased by the amount as for the point of maximum efficiency. No parts of the turbines shall be shipped before the tests are completed.

The efficiency of the turbines as so determined by the tests, for each point corresponding to the contractor's efficiency guarantees, shall not be less than that guaranteed. As determined by the tests, at the point of best efficiency when operating at a speed corresponding to a head of 70 feet on the turbine, the efficiency (percent) of the model shall not differ by more than one from the maximum efficiency (percent) of the model when operating at any speed.

The cavitation limits of the turbines shall be determined by the model tests, under corresponding conditions of headwater and tailwater levels sufficient to cover the entire operating range to be expected in service and the contractor's cavitation guarantees.

To determine the cavitation limit of each of the turbines for any desired power output and head, the model shall be tested under homologous conditions by operating it at a constant speed corresponding to such desired head, at a fixed gate opening and runner-blade tilt suitable to produce a power output corresponding to such desired power output, under a constant head on the model, and by varying the test tailwater level. The efficiency, the discharge (flow of water), and the power output of the model shall be determined for the various tailwater levels of the test.

The cavitation limit of the turbines for such desired power output and head shall be the tailwater level corresponding to the lowest tailwater level of such test below which the efficiency, the discharge and the power output of the test cease to remain constant. Corresponding tailwater levels shall be those for which the cavitation coefficients are equal.

SEC. 75. *Turbine capacity tests.*—The capacity of the turbines shall be determined by tests of one of them, to be made by the Authority after installation has been completed and the unit placed in operation.

The capacity shall be determined as follows:

> The power output of the generator shall be determined by the use of properly calibrated electrical instruments.
> The power delivered by the turbine to the generator shall be determined by dividing the generator output by the guaranteed efficiency of the generator, or should the generator have been tested, by the resulting efficiency.

The turbine shall be thus tested under each of the heads upon which the contractor's guarantees of capacity have been based, as nearly as it is practicable to attain such heads, and the capacity under each head of the test shall be the maximum power the turbine can deliver to the generator at such head.

The head shall be the difference between the headwater level measured upstream of the intake (at a quiescent point) and the undisturbed tailwater level in the tailrace corrected for the loss of head through the trashracks unless they are removed. The details of the test shall be in accordance with the applicable test code of the American Society of Mechanical Engineers, and the contractor shall be notified sufficiently in advance of each test, so that he may have a representative present if he desires.

SEC. 76. *Governor tests.*—During or following the capacity test the governors will be tested as necessary to demonstrate that the various control, regulating, and protective devices function properly and that the entire governor systems are adequate and satisfactory for the purpose.

ITEM 3. SPARE PARTS

SEC. 77. *Spare parts.*—Under item 3 the contractor shall furnish and deliver one set of the following spare parts for the turbine:

a. One complete set of wearing parts for a turbine guide bearing.

b. Three gate stem levers or arms with links.

c. One complete set of breaking pins or links for the gate-operating mechanism.

d. One d.c. motor for use with automatic greasing system. (This motor required only if grease-lubricated turbine guide bearing is provided.)

Spare parts shall be interchangeable with and of the same material and workmanship as the corresponding parts of the turbine.

ITEM 4. CHANGE IN LENGTH OF SHAFT

SEC. 78. *Price adjustment for change in turbine shaft length.*—If for any reason the length of the shaft be changed from the specified in section 7, there shall be added to or deducted from the contract price for item 1, as the case may be, for each foot of increase or decrease the corresponding contract price for item 4 with fractional parts thereof for fractional parts of a foot.

ITEM 5. CHANGE IN LENGTH OF PIT LINER

SEC. 79. *Price adjustment for change in length of pit liner.*—If the length of the pit liner be changed from that specified in section 7, there shall be added to or deducted from the price for item 1, as the case may be, for each pound of metal added to or deducted from the pit liner the corresponding contract price for item 5.

ITEM 6. GENERATOR INSPECTION PLATFORM

SEC. 80. *Generator inspection platform.*—Under item 6 the contractor shall furnish and deliver a suitable platform for access to the lower parts of the generator. The platform shall be capable of supporting a half thrust bearing runner. It shall be located in the turbine pit and shall be supported from the generator bearing bracket or from the turbine pit walls. It shall be designed so as to be readily removed to allow dismantling the turbine from above.

Suitable provision shall be made for access to the inspection platform, either by a stairway or ladder from the turbine deck or from the entrance stairs.

SPECIFICATION NO. 4142, HYDRAULIC TURBINES AND GOVERNORS FOR UNITS 1, 2, AND 3, BOONE PROJECT

(Reference drawings not included in this report)

GENERAL PROVISIONS

SEC. 1. *The requirement.*—The work covered by these specifications comprises designing, furnishing, and delivering three vertical shaft hydraulic turbines of the single Francis runner type, with riveted or welded plate steel scroll case, for direct connection to alternating-current generators; designing, furnishing, and delivering three oil-pressure governing systems; and certain other work as hereinafter set forth, all for generating units Nos. 1, 2, and 3 of the Boone power plant.

The contractor shall furnish the materials and do the work required by such of the above items as are included in the contract.

SEC. 2. *General description.*—Boone Dam and power plant will be located in Tennessee on the South Fork of the Holston River on the Sullivan-Washington County line about 10 air miles from Johnson City and Kingsport and 18 air miles from Bristol, Tennessee-Virginia. There will be a railway siding to the power plant from the Clinchfield Railway at Gray, Tenn.

The dam will be of the gravity type with the power plant located immediately downstream of the dam, with approximately 100 feet of penstock extending from the upstream face of the dam to the center line of the turbine.

The project will be operated as a headwater storage development for regulating the flow of the Tennessee River. The plant will operate on a low annual load factor with some of the units motoring during the balance of the year.

The power plant will be designed and constructed to contain three 34,500-hp. turbines, each direct-connected to a 27,777–kv.-a., 0.9 power factor, 3-ph., 60-cycle, 13,800-v. generator. Station service will be 440 v., 3 ph., 60 cycles, with 250-v. d.c. auxiliary supply and 48-v. d.c. annunciator supply.

The turbines shall each have a capacity of 34,500 hp. at full gate under 90-foot net head, and shall be designed to produce best efficiency when operating at approximately 110-foot net head. The gross head will vary from a maximum of 123 feet to a low of 65 feet.

SEC. 3. *The engineer.*—Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the Engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

SEC. 4. *Authority's drawings.*—The work is shown on the accompanying drawings which bear the general title "Boone Project" and are designated as follows:

Drawing No.	*Title*
41N1	General Plans and Sections
41N2	General Plans and Sections

Such supplementary drawings, further detailing the above, as may be necessary, will be furnished by the Authority during the progress of the work.

The contractor will not be held responsible for the correctness of the Authority's design, but he shall carefully check all dimensions and quantities on drawings and schedules furnished by the Authority and shall advise the engineer of any errors or omissions discovered.

The Authority will furnish the contractor, without charge, necessary copies of the contract and specifications and such number of prints of the Authority's drawings as may reasonably be required for the work.

SEC. 5. *Drawings to be furnished by the contractor.*—The contractor will be required to furnish assembly and detail drawings, wiring diagrams, and cuts of the work in such number and detail as necessary for installation, operation,

and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.

Such drawings shall include but shall not be limited to the following:

a. Preliminary and final detail drawings of the draft tube and scroll case.

b. Foundation drawings of all parts set into or coming in contact with concrete, showing method of supporting and method of anchoring into concrete.

c. Detailed drawings of all parts bedded in concrete.

d. Detailed drawings of all parts connecting to or related to equipment supplied by other manufacturers or to equipment furnished by the Authority.

e. All piping drawings, wiring diagrams, and drawings showing the method of lubricating parts.

f. Details of all parts which may require adjustment or are subject to wear.

g. Assembly sections and plans of the entire turbine.

h. Subassembly sections and plans of the principal component parts including:

(1) Operating cylinders or servomotors.
(2) Main bearing and housing and stuffing box.
(3) The gate-operating mechanism, including shifting ring, links, levers, pins, connections which operate the guide vanes and guide vane bearings.

i. Drains and air vents.

j. Assembly sections and plans of the governor.

k. Such subassemblies, cuts, illustrations, or drawings as are necessary to illustrate the functioning of the various parts of the governor.

l. Piping and arrangement drawings of the governor and accessories.

m. Foundation drawings for the governor and pressure tank.

n. Detail drawing of the pressure tank.

o. Detail drawing of the front of the governor cabinets, showing the location of the various instruments.

p. Details of the mounting and dimensions of the individual instruments.

q. Wiring diagrams showing the electrical connections for the governor apparatus and all electrical instruments or equipment.

All drawings shall show the material, dimensions, finish, fits, clearances, tolerances, bolting, and such other information as may be necessary to demonstrate compliance with the requirements of the specifications.

Within 30 days after date of notice of award the contractor shall submit four copies of a list of all drawings he proposes to furnish, identifying each by serial number and a descriptive title and giving expected date of submission. This list shall be revised and extended as necessary during the progress of the work.

The contractor shall permit the engineer to examine such of contractor's shop drawings as may be necessary to enable him to determine the efficiency of the contractor's design. The contractor shall provide the engineer with copies of such of his design data as may be required by the engineer for the purpose.

Six prints of each drawing shall be submitted to the engineer for approval and in such sequence that he will have all information necessary for checking.

The engineer will, within 10 days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Correction."

The contractor shall make necessary corrections and revisions on drawings marked "Approved with Corrections as Noted" and on drawings marked "Returned for Correction," and he shall submit prints for approval in the same routine as before. Time required for such revision of drawings and resubmission of prints shall not entitle the contractor to any extension of time, but the engineer will examine and return such prints as promptly as possible.

Any work done or material ordered by the contractor prior to receipt of drawings "Approved" or "Approved with Corrections as Noted" by the engineer shall be at the contractor's risk.

After print of any drawings has been returned "Approved," the contractor may release to his shop for production all the parts covered by the approval. When the approval covers an assembly or group of such parts, the contractor shall furnish one print of each shop drawing of such parts to the Authority's inspector at his plant, and a second print of each such shop drawing shall be furnished to the engineer at the time when issued for production.

Drawings shall be made in a manner to give clear, permanent reproductions. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract, and shall be signed by a responsible representative of the contractor.

Approval by the engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

If, at any time before the completion of the work, changes are made necessitating the revision of approved drawings, the contractor shall make such revisions and proceed in the same routine as for the original approval.

Upon completion of all work, the Contractor shall furnish the Authority one set of vandyke negatives on thin paper and one complete set of prints which shall be on cloth of all drawings approved by the engineer, including all corrections and revisions made up to the time of completion of the work.

SEC. 6. *Work to be done and materials to be furnished by the Authority.*—The Authority will construct the substructure with the turbine and will construct the draft tubes in accordance with the contractor's design.

The Authority will unload the turbine, the governor, and all necessary equipment at the point of delivery; will install them; will do all necessary field drilling and reaming of holes; will do all field riveting, caulking, and welding; and will make the efficiency and capacity tests after installation is complete.

The Authority will furnish the following miscellaneous accessories:

a. All piping outside the speed ring and pit liner not otherwise provided for, except the following:

(1) The piping and connections to the pressure and vacuum gauges.

(2) The governing system piping and connections to the turbine.

b. All electrical connections throughout and all alarms, signals, and electrical devices outside the turbine pit, except as specified to be furnished with the turbine or the governing system.

c. Instruments, gauges, and the like required for the turbine efficiency and capacity tests.

d. Oil for the governing system and turbine, except governor dash pot oil.

SEC. 7. *Work to be done and materials to be furnished by contractor.*—The turbine contractor shall design, furnish, and deliver each turbine with auxiliary equipment, piping, and all necessary accessories complete within the limits given below, except as otherwise specified in section 6:

a. Up to the face of the generator shaft half coupling, 14 feet above the center line of the scroll case.

b. Up to the top of the turbine pit liner, 17 feet above the center line of the scroll case.

c. Down to the lower end of the draft tube liner, ending 18 feet below the center line of the scroll case.

d. Including piping within the turbine pit and accessories for oil supply for the turbine guide bearing.

e. Including the turbine bearing thermometers to be mounted on the governor cabinet.

f. Including the turbine atmospheric air vent valve, with piping and connections to outside the turbine pit.

g. All stairs, platforms, railings, and guards required within the turbine pit not otherwise provided.

h. All bolts, anchor bolts, eyebolts, erection bolts, leveling jacks, rivets, gauges, templates, special reamers and tools needed for erection.

i. One complete set of wrenches and special tools with board required for dismantling and assembling the turbine.

j. One lifting device for runner and shaft assembly.

The governor contractor shall design furnish, and deliver the governing system complete with remote and auxiliary control mechanisms, oil supply system, pumps, tanks, all governor piping down to the turbine servomotors, gauges, instruments, and all necessary accessories with foundation bolts and any special tools necessary for erection, adjusting, or dismantling.

SEC. 8. *Contractor to cooperate with others.*—The contractor shall cooperate with the manufacturer of the generator and the manufacturers of other related equipment in the mutual exchange of drawings, dimensions, templates, gauges,

and other information to the extent necessary to ensure the complete co-ordination of the design, arrangement, and manufacture of all related parts. Copies or prints of all data so exchanged shall be furnished by the engineer.

SEC. 9. *Materials and workmanship.*—Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

Where the characteristics of any material are not explicitly specified, approved material meeting the requirements of the appropriate specifications of the American Society for Testing Materials or other recognized standard shall be employed.

Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust.

Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

Castings shall be true to drawings, homogeneous, free from objectionable nonmetallic inclusions, and free from excessive segregation of impurities or alloys.

A casting having any dimension less than called for in the drawing, sufficient to impair its strength by more than 10 percent or to increase the stresses to above the limits specified, shall be rejected.

No casting shall be repaired without the approval of the engineer. Castings to be repaired shall be chipped to sound, clean metal, but if such chipping reduces any stress-resisting cross section more than 20 percent, the casting may be rejected. Casting repaired by welding after annealing shall be re-annealed, if required.

The design of welded joints and welded connections and the fabrication of welded steel parts shall conform to the applicable paragraphs of the Boiler Construction Code of the American Society of Mechanical Engineers, section VIII for Unfired Pressure Vessels. Welding shall conform to paragraph U69 and shall be stress-relieved, except draft tube liner and minor details, welding for which shall conform to paragraph U70.

SEC. 10. *Access to work.*—The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where materials or equipment are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such materials or equipment.

The contractor shall furnish suitable office space, equipment, and telephone facilities to enable the Authority's representative to perform his official duties.

SEC. 11. *Shop inspection and material orders.*—No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

The contractor shall, at his expense, prepare specimens and perform tests and analyses in accordance with standard practice, as required to demonstrate conformance of the various materials with the pertinent specifications, under the direction and in the presence of the inspector. The contractor shall, when requested, furnish to the engineer certified test reports in triplicate of all required tests and analyses.

The contractor shall also furnish to the engineer test pieces and samples for independent analysis and test, as requested.

The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

The contractor shall furnish to the engineer and to the contracting officer a list of subcontractors and vendors with whom orders are to be placed for materials or equipment which will enter directly into the work of this contract. Triplicate copies of material or equipment orders and lists of contractor's stock material or equipment required is this contract shall be furnished to the engineer with one additional copy to the contracting officer.

All orders and stock lists shall state the specification designation under which the material is to be furnished and shall bear reference to the drawing and part number, if any, pertinent thereto. Orders shall also state that material is subject to inspection and testing and shall show the required date of delivery of the material to the contractor's plant.

The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

SEC. 12. *Marking.*—All parts or units of assembly shall be marked or tagged with piece marks. Marks shall be in accordance with approved erection drawings, shall be clearly legible and so placed as to be readily visible when the part is being erected in the field. All pieces weighing more than one ton shall have the approximate weight marked thereon.

Connecting parts assembled in the shop shall, before dismantling for shipment, be match-marked to facilitate erection in the field. The location of the match marks shall be clearly indicated on erection drawings furnished by the contractor. All parts or assembly of parts shall also be so marked as to identify them with this contract.

SEC. 13. *Preparation for shipment.*—The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

The turbine shaft, under item 1, shall be shipped by the contractor, at his own cost and risk, to the generator manufacturer, if so stipulated. The delivery of the shaft from the plant of the generator manufacturer to the field will be made by the generator manufacturer without cost or risk to the contractor.

ITEM 1. THREE 34,500 HORSEPOWER TURBINES

SEC. 14. *Capacity of turbines.*—The contractor under item 1 shall design, furnish, and deliver three 34,500-hp. vertical shaft hydraulic turbines with single Francis type runners.

The turbines shall have a capacity of not less than 34,500 hp. at full gate under a net head of 90 feet, and shall be designed and constructed to operate satisfactorily at any gate opening and any load that such a turbine will develop up to 41,500 hp. or up to the limits covered by the cavitation guarantees under any gross head between 65 and 123 feet.

The turbines shall be designed to have maximum efficiency when operating under a net head of approximately 110 feet. The normal speed shall be 100 r.p.m. and the rotation counterclockwise as viewed from above.

SEC. 15. *Operating conditions for the turbines.*—The turbines shall operate under the conditions of head, headwater, and tailwater as follows:

Headwater elevation, feet:	
Maximum power storage	1385
Minimum	1330
Tailwater elevation, feet:	
Zero flow	1263
5,000 c.f.s.	1264.6
10,000 c.f.s.	1266.2
15,000 c.f.s.	1267.6

During floods, tailwater will rise considerably higher.

Operating head, feet:	
Maximum gross	123
Minimum gross	65
Net head for turbine rating	90
Net head for best efficiency (approximate)	110

Design and construction

SEC. 16. *General.*—The contractor shall make and shall be responsible for the design of the work. It shall be a coordinated and adequate design ful-

filling the requirements of these specifications and conforming to the best engineering practice. The parts shall be designed for convenient and economical maintenance, erection, and dismantling, and suitably designed for shipping and hauling to the site. The design shall conform to the dimensions of the substructure as shown on the accompanying Authority's drawings. There will be one 150-ton crane available for the erection and dismantling of the units.

SEC. 17. *Limiting stresses.*—In the design of the turbine, each part shall be so proportioned that the maximum unit stresses therein, resulting from any operating condition, shall not exceed one-third the elastic limit or one-fifth the ultimate strength of the material, whichever be the lesser, *except as hereinafter specified.* At the breaking point of the yielding link or shearing pin of the guide vane operating mechanism, a unit stress not to exceed two-thirds the elastic limit will be permitted in the wicket gates, the gate stems, and gate-operating levers. In case of temporary overload, as described in the section of the specifications entitled "Operating Requirements," unit stresses not exceeding one-half the elastic limit will be permitted.

The contractor shall furnish data as to the computed unit stresses necessary to enable the engineer to check the design.

SEC. 18. *Turbine operating requirements.*—The turbine shall operate at any gate opening and under any head from 123 feet to 65 feet and within the outputs covered by the cavitation and capacity guarantees without causing objectionable surges in power output, detrimental vibrations, or objectionable noises other than those due to the resonance of the substructure.

All parts of the turbine shall be constructed to withstand without injury, for as long as 1 hour, the maximum runaway speed under the maximum head and no load.

The Authority will use every reasonable precaution to limit the output of the turbine to the maximum loads specified and guaranteed by the contractor; however, the turbine shall be so designed and constructed that a temporary overload produced by a combination of maximum load specified and full gate opening shall cause no damage. In making provision for such overload the unit stresses in the parts may be increased as specified in section 17.

SEC. 19. *Cavitation.*—The runner ring of the turbine shall be free from excessive cavitation, or pitting, for a period of not less than one year after the turbine is placed in commercial operation, provided that the turbine shall not be operated at loads less than minimum output horsepower stated by the contractor in his cavitation guarantees for more than 800 hours during the year and, furthermore, provided that the turbine shall not be operated at outputs greater than the maximum output horsepowers stated by the contractor in his cavitation guarantees for more than 50 hours during the year.

Excessive cavitation, or pitting shall be defined as the removal of metal from the runner aggregating 600 cubic inches or more, or a reduction in thickness of metal at any point of 15 percent or more.

If, within the 1-year period after being placed in commercial operation and under the above operating conditions, a turbine runner or other part is pitted so that over any continuous surface area of 4 square inches or more the metal is reduced in mean thickness by $\frac{3}{16}$ inch or more, the contractor shall repair all pitted places in a satisfactory manner by welding with stainless steel. For this purpose the Authority will unwater the unit, provide the necessary platforms, compressed air, welding machines and electric power, and the contractor shall furnish all other necessary tools, materials, and labor.

Damage resulting from the chemical composition of the water shall not be considered as "cavitation" or "pitting" within the meaning of the words as used in this specification.

In case of delay, through no fault of the contractor, in the placing of the turbine in commercial operation, the period of guarantee shall expire not later than 30 months from the date of final shipment.

SEC. 20. *Turbine runner.*—The turbine runner shall be of the Francis type and shall be an integral steel casting. The runner shall be designed to support the weight of the rotating parts of the turbine, including the shaft, on a flange on the bottom of the discharge ring or on the speed ring. The runner

shall be securely bolted to the flange on the lower end of the shaft. Renewable wearing rings shall be provided on the runner.

All surfaces exposed to the flow of water shall be finished smooth by grinding or other means so as to be free from hollows, depressions, cracks, or projections which might cause cavitation.

A cone attached to the hub shall be provided to guide the water as it leaves the runner. The entire runner shall be carefully balanced before leaving the shop. Openings shall be provided through the runner crown to drain the water and reduce the hydraulic thrust.

SEC. 21. *Turbine shaft.*—The shaft shall be an open-hearth carbon or alloy steel forging, heat-treated as necessary, machined all over, and hollow-bored throughout its length. The bore shall be smooth-finished to facilitate inspection of the metal in the interior of the shaft. The shaft shall be polished where it passes through the guide bearing and finished smooth all over.

The shaft shall be provided with a removable sleeve where passing through the stuffing box in the head cover. The sleeve shall be of corrosion-resisting steel or other approved corrosion-resistant mate.ial, accurately machined, polished, and adequately secured to the shaft.

The lower end of the shaft shall be provided with a flange for bolting to the runner. The upper end of the shaft shall also be provided with a flange which, with the mating flange of the generator shaft, shall form the coupling between the two shafts.

The contractor shall design, in cooperation with the generator manufacturer, the entire coupling between his work and the generator shaft, but the generator manufacturer will provide the generator half coupling and the coupling bolts and will make the coupling connection in the field assembly. Each contractor shall provide a suitable guard for his half coupling.

Both the upper and lower couplings shall be of the male and female type with a sliding fit between the tongue of the male half and the socket of the female half. All shaft coupling and coupling bolts shall be in accordance with ASA–B 49.1–1947 standards as to size and clearances.

The Contractor under item 1 shall at his expense ship the turbine shaft to the generator manufacturer as the engineer directs. When so shipped the parts shall be completely fabricated, assembled, and inspected except that the contractor shall only rough-drill the turbine half coupling to a metal template, which shall precede the shaft to the generator manufacturer for use in rough-drilling the generator half of the coupling. The template shall be furnished by the Contractor. The generator manufacturer will connect the turbine and generator shafts, check their alignment, make all necessary corrections, ream the holes in the flanges of both turbine and generator shafts, furnish the bolts and nuts, and fit the bolts. After fitting by the generator manufacturer, the parts will be shipped direct to destination at the expense of the generator manufacturer.

SEC. 22. *Turbine guide bearing.*—The turbine shall be provided with an oil-lubricated guide bearing with suitable babbitt lining for the shaft. The bearing shall be located above the stuffing box with space to remove or replace the gland and packing. The runner, shaft, and bearing shall be arranged to permit at least ¾-inch vertical movement of the rotating parts of the turbine for adjusting and dismantling the unit thrust bearing. The guide bearing support or housing shall be of heavy construction, fastened in the head cover and designed to support the bearing shell rigidly. The bearing shell shall be split vertically to facilitate dismantling.

The bearing shall be accurately bored, suitably grooved for oil circulation, and scraped to proper fit on the shaft. Suitable lifting eyes and jackscrews shall be provided to facilitate removing and replacing the bearing.

Lubrication of the bearing shall be by oil, circulated through the bearing. Circulation shall be from the reservoir below the bearing through the oil pumps to the reservoir about the bearing, then by gravity through the bearing to the lower reservoir. If cooling of the oil is necessary, suitable cooling coils, through which cold water from the scroll case can be circulated, shall be provided in the oil reservoir, but cooling coils shall not be placed in the bearing housing. The lubricating system shall have sufficient capacity to supply an ample amount of oil to the bearing, and the lower oil reservoir shall be sufficient to hold all the oil in the entire system. The upper reservoir shall be connected to the lower reservoir by an overflow pipe, the size of which

shall be sufficient to hold the oil level in the upper reservoir practically constant with one or two pumps operating.

Two independent approved electric-motor-driven positive displacement rotary oil pumps of the gear or screw type shall be provided for circulating the oil. The pumps shall be mounted in an alcove provided in the turbine pit liner or other convenient location. One oil pump shall be driven by a 3-ph., 60-cycle, 440-v. motor and the other by a 250-v. direct-current motor. The pump motors shall have weatherproof frames with enclosed conduit boxes, insulation impregnated against moisture and oil, and ball bearings in dustproof housings, with adequate means of retaining the correct amount of lubricant without dripping. Capacity speed and torque of the motors shall be suitable for the pump requirements. Motors shall be designed for full-voltage starting and shall conform to NEMA and AIEE standards.

Normally the oil shall be circulated by the alternating-current motor-driven pump, and the direct-current motor-driven pump shall be arranged to start automatically and supply oil to the bearing upon failure of the alternating-current motor-driven pump to supply sufficient oil to the bearing. Two float switches, each having two independent 250-v. direct-current contacts, shall be provided—one contact on float A for shutting down the unit when the oil level in the upper reservoir reaches a predetermined low level position, the other contact on float A for preventing the starting of the unit until the oil level in the upper reservoir has reached a predetermined normal level position. One contact on float B for starting the direct-current motor-driven pump when the oil level in the upper reservoir reaches a predetermined low level position and the other contact on float B for shutting down the direct-current motor-driven pump when the oil level in the upper reservoir reaches a predetermined normal level position. A contactor for the direct-current oil pump motor shall be provided; it shall be 3 pole and shall have four auxiliary switches. The contactor shall have an enclosed rating of not less than 45 amps. An oil flow indicator shall be provided. It shall have one 250-v. direct-current contact for connection to an alarm provided by the Authority. A bearing thermal relay shall be provided for mounting in the turbine pit. It shall be of the manual reset type for emergency shut-down. Wiring to the governor shut-down mechanism shall be provided by the Authority. A manually operated control switch for each pump motor with indicating lights shall be furnished by the contractor under item 2 for mounting on the governor cabinet. Local control switches for mounting inside the turbine pit will be supplied by the Authority. Each pump shall be supplied with a pressure gauge, which shall be mounted on the equipment or at some convenient point inside the turbine pit.

The contractor, under item 1, shall furnish two suitable remote indicating mercury-type thermometers with 250-v. contacts—one for alarm and one for shut-down, located in the babbitted surface of the bearing shell. The indicators shall be located on the governor cabinet and shall be mounted by the contractor under item 2.

The contractor, under item 1, shall provide two temperature detectors in the guide bearing shell and one in the lower oil reservoir. The temperature detectors shall be of the resistance type, 10 ohms at 25° C., 250 v., AIEE standard, and will be connected to the micromax temperature recorder furnished by the contractor, under item 2, mounted on the governor cabinet.

The contractor shall furnish the lubricating system for the bearing complete as specified and including sight-flow indicator, pressure gauges, piping, oil level indicator for the oil reservoir, and all necessary switches, relays, and other accessories for the safe and automatic operation of the system. All piping, valves, and fittings shall be of brass. All wiring for power supply to the motors, alarms, and protective apparatus will be furnished by the Authority. The design and construction shall be such that under any operating conditions of the turbine, no water shall enter the guide bearing lubricating system, and there shall be no appreciable leakage of oil past the lower oil shedder or by overflow from any part of the system.

SEC. 23. *Turbine scroll case.*—The scroll case will be constructed by the Authority and will be formed in the concrete substructure. The contractor shall furnish the complete design of the casing, but the overall dimensions shall conform to the dimensions shown on the Authority's accompanying drawings.

The contractor shall provide a door frame and door for access from a passageway in the substructure to the interior of the scroll case. The clear opening for the door shall be 30 inches wide by 48 inches high. The door frame shall

be of cast steel, ribbed, of rigid construction, designed for embedding in the concrete, and complete with anchor bolts. The frame for the door shall form a lining for the access tunnel for a distance of not less than 30 inches.

The door shall be hinged to swing into the scroll case and when closed shall be flush with the interior of the case. It shall be so stiffened as to prevent vibration. The door shall be of cast or steel plate construction designed to withstand, and be tight, under maximum headwater conditions. Both the door and its frame shall be machined on their sealing surfaces and provided with jackscrews and a sealing gasket. Hinge pins, bolts, and washers for the door shall be of bronze. A test cock shall be provided to determine whether the water level in the scroll case is below the sill of the door.

SEC. 24. *Speed ring.*—The speed ring shall be designed to withstand all stresses to which it may be subjected during installation, operation and dismantling, including those occasioned by the weight of substructure masonry, of the generator, and of the turbine, and by hydraulic thrust and water pressure.

The speed ring shall be made of steel castings and shall consist of upper and lower flanges connected by integral columns. The flanges shall be provided for bolted connections between the ring and the pit liner, head cover, and discharge ring if a separate ring is used.

Jacks, jack pads, and anchor bolts shall be provided for supporting and leveling the speed ring in position. Grout holes shall be provided in the lower flange to facilitate placing concrete under that section. Bolts of sufficient size and number shall be provided to anchor securely the upper and lower flanges to the concrete.

SEC. 25. *Head cover.*—The head cover shall be of plate steel, cast steel, or cast iron. It shall be designed to withstand any possible internal water pressure. The under side of the head cover shall be designed to minimize friction and eddy losses between it and the runner, and the space between shall be adequately drained to relieve water pressure and to minimize hydraulic thrust and leakage. Two seal or wearing rings shall be provided adjacent to the top of the runner.

The head cover shall be designed so that it may be removed or replaced with the runner and shaft in place. The design shall be such as to permit a vertical movement of at least three-quarter inch of the runner and shaft when assembled. An automatic valve and the necessary piping to outside the turbine pit shall be provided for the admission of free air to the space below the runner. A valve and the necessary piping shall be provided for the admission of compressed air to the space below the runner to be used when motoring the unit.

Stuffing boxes for each wicket gate or guide vane shall be provided in the head cover. All bolts and nuts used in connection with the stuffing boxes shall be of noncorrodible metal. Two bronze-lined guide bearings for each gate stem shall be provided in the head cover, one above and one below the stuffing box.

The stuffing box for the turbine shaft shall be provided in the head cover above the runner and shall be designed so that it can be repacked and adjusted without disturbing the guide bearing. The gland and bolts shall be of noncorrodible metal, and the stuffing box shall be provided with a noncorrodible metal seal ring. A suitable system for the water lubrication of the packing and for the disposal of leakage shall be provided.

SEC. 26. *Bottom ring.*—A bottom ring shall be provided of steel castings sectionalized as necessary, and it shall be designed to be bolted to and to be removable from the speed ring or the discharge ring. A bronze-lined guide bearing shall be provided in this ring for the lower stem of each guide vane. A seal or wearing ring shall be provided to mate with the ring on the lower band of the runner.

SEC. 27. *Discharge ring.*—The discharge ring shall be of cast steel or plate steel, designed to be permanently set in the concrete substructure and heavily ribbed to secure proper anchorage to the concrete. It shall be securely bolted to the speed ring and shall extend to below the bottom of the runner. The lower end shall connect to the draft tube liner. The upper face of the discharge ring shall form a seat to which the bottom plate shall be securely bolted. The lower end shall be provided with a flange to support the turbine

runner and shaft when the latter is disconnected from the generator shaft. Suitable pads, jacks, and anchor bolts shall be provided to support and level the ring while being attached to the draft tube liner and concreted in place. Suitable grout holes shall be tapped in the upper face if necessary and plugs furnished.

The bottom ring and discharge ring may be combined in one ring if better suited to the contractor's design.

SEC. 28. *Guide vanes and operating mechanism.*—Each guide vane and its stems shall be an integral steel casting. The contacting surfaces of gates and the gate stems shall be machine-finished, and the surfaces of the gates shall be ground smooth. Each gate shall be provided with three bronze-bushed greased-lubricated guide bearings, one in the bottom ring and two in the head cover (one below and the other above the stuffing box). The gate stems, where passing through the two bearings adjacent to the water passages and through the stuffing boxes in the head cover, shall be protected with suitable noncorrodible metal sleeves, shrunk onto the stems. Each gate stem shall be provided with a suitable thrust bearing above the stuffing box, arranged to resist the thrust in either direction and adjustable to support the gate in position midway between the bottom ring and the head cover. All gates shall be interchangeable.

The grease piping leading to the bottom wicket gate bearing shall be three-eighth inch and of noncorrodible metal. The grease connection shall be made to the upper end of the pipe by means of an antifriction type swivel. The entire grease piping and connections to the bottom bearings of each gate shall be tested in the shop under a pressure of 4,000 psi.

Check valves shall be provided between the bearings and the grease fitting where the bearings are subject to water pressure.

An automatic pressure greasing system shall be provided to lubricate each part of the gate mechanism having relative motion in contact. The system shall be designed so that it will deliver a measured quantity of Velox No. 3 grease to each bearing. No measuring valve shall contain either check valves or springs in its design.

The central pumping station shall be self-contained and equipped with a grease pump with positive mechanically driven valving. The grease pump may be operated by air or electric motor. Air-operated pumps shall be suitable for use with compressed air at 80 to 120 psi. Electric motors shall be suitable for use with single-phase, 60-cycle, 115-v. current. The grease pumping mechanism shall be arranged so that a standard commercial grease drum of 400-pound capacity may be used as the grease reservoir.

The system shall be provided with an adjustable timing mechanism suitable for operation with single-phase, 60-cycle, 115-v. current. This timing mechanism shall cause the system to grease each bearing at least once every 24 hours. The volume of grease applied to each bearing which is subjected to water pressure shall be sufficient when using the minimum setting of the adjustable timer to completely fill the clearance between the bearing surfaces once every 48 hours. The volume of grease applied to the bearings not subjected to water pressure shall be sufficient, when using the minimum setting of the adjustable timer, to completely fill the clearance between the bearing surfaces once every 96 hours, except the bearings under the gate ring, for which the volume shall be two-thirds less for each unit area of bearing surface. The volume of grease required to fill the space between bearing surfaces shall be determined on the basis of 0.002-inch clearance plus 0.001-inch increase in clearance for each 1-inch increase in diameter of the bearing.

All piping and hose between the pump and point of lubrication shall be arranged as inconspicuously as possible, and the arrangement shall be such that the minimum number of connections need be broken when dismantling the turbine.

The gate-operating mechanism shall be of ample strength to withstand the maximum load that can be imposed upon it under any operating condition. The entire mechanism shall be of the outside type and so mounted within the turbine pit as to be readily accessible for inspection, adjustment, or repair. The gate-shifting ring shall be a steel casting or of welded steel-plate construction, of rigid construction, and provided with renewable bronze guides.

Parts of the mechanism having relative motion in contact shall be bronze-bushed and provided with forced-grease lubrication. The design shall be such that lost motion and wear shall be reduced to a minimum, and adequate means shall be provided for adjusting the position of each gate independently. A

breaking pin or yielding part shall be provided between each gate stem and the gate-shifting ring of sufficient strength to withstand the maximum operating forces but having a breaking or yielding strength sufficiently low to protect the other parts of the mechanism should one or more of the gates become blocked. The breaking pin shall be designed so as to fail should the breaking force be in either direction.

The angular movement of the gates shall be so limited and the mechanism so designed that the failure of a breaking pin will not interfere with the operation of the other gates or other parts of the turbine.

Each gate shall be in hydraulic balance at some point below 30 percent of full gate opening and shall tend to drift to the balanced position in case of breaking of its connection to the operating mechanism.

SEC. 29. *Wearing rings and plates.*—Removable and renewable wearing rings shall be provided where there are close running clearances between the runner and stationary part of the turbine, and removable and renewable wearing plates of steel or bronze shall be provided on the stationary parts above and below the wicket gates. The wearing rings shall be of suitable metal. The wearing rings and wearing plates shall be securely fastened in place by approved means. The arrangement of the rings shall permit at least three-quarter-inch vertical movement of the runner. Provision shall be made to supply water to the spaces between the runner and the upper stationary ring for cooling and for lubrication when motoring the unit with the gates closed. Suitable valves and the necessary piping, gauges, flow indicators with alarm contacts, and accessories shall be provided.

SEC. 30. *Servomotors.*—The turbine shall be equipped with two oil-operated, double-acting hydraulic cylinders, or servomotors, the combined capacity of which shall be sufficient to operate the gates when supplied with oil at a minimum pressure of 250 psi. With an adequate supply of oil at the minimum pressure, the two servomotors shall be capable, under maximum head conditions, of moving the turbine gates a full opening stroke in four seconds and a full closing stroke in 4 seconds.

The servomotors shall be so designed and constructed that the work of moving the gates shall be divided approximately equally between the two, and the forces applied in approximately equal magnitude on opposite sides of the gate-shifting ring.

The cylinders shall be accurately bored, provided with flanges for the connection of piping and with long stuffing boxes to prevent oil leakage along the piston rods. Pistons shall be of cast steel, or cast iron, each fitted with not less than three cast-iron piston rings shaped to give close contact and uniform pressure on the cylinder walls and to prevent oil leakage past the pistons. The necessary piping and restoring rods or cable to connect to the governor shall be furnished.

The servomotors shall be equipped with means of making adjustments whereby the rate of closing may be sufficiently retarded between the speed-no-load position for maximum head and the fully closed position to prevent shock to the gate-operating mechanism when the gate surfaces contact.

Suitable mechanical locking devices shall be provided so that the turbine gates may be held in the open or in the closed position against the maximum oil pressure. Such devices shall be designed for convenient use and shall be of the screw type, operated by a handwheel, or equal. They shall be permanently mounted on the outboard bearing or cross-head guide. A suitable adjustable stop shall be provided to limit the stroke to prevent overloading the generator during periods of high head.

The cylinders of the servomotor shall be provided with machined mounting pads and mounted on corresponding pads on either the pit liner or the scroll case.

An outboard bearing or cross-head guide shall be provided beyond the stuffing box of each cylinder to stiffen the piston rod. Provision shall be made for collection and disposal of any oil leakage past the stuffing box.

Each servomotor shall be tested in the shop with warm oil or kerosene at a pressure of 450 psi and shall be tight when so tested.

SEC. 31. *Pit liner.*—A pit liner shall be provided of welded steel plate, heavily ribbed for anchorage to the concrete. It shall have a flange on the bottom bolted to a flange on the speed ring and shall extend above the servo-

motors up to the elevation specified. It shall be constructed in sections with bolted flanged connections.

Suitable provision shall be made to support the operating cylinders and transmit their reaction either to the speed ring or to the concrete, if the cylinders are bolted to the pit liner.

A drain consisting of perforated pipe or channels shall be welded to the outside of the liner near its top to intercept any moisture seeping up between the concrete and the metal, and drain connections shall be provided to dispose of such leakage.

Sec. 32. *Draft tube.*—The draft tube will be constructed by the Authority and will be formed in the concrete of the substructure. The contractor shall furnish the complete design for the draft tube, which shall be of the elbow type. The contractor shall provide a draft tube liner of steel plates with welded or riveted joints. It shall extend from the bottom of the discharge ring or the speed ring the distance hereinbefore specified. The interior of the liner shall be flush and smooth and shall have no abrupt changes in direction. The design shall be such as to reduce to a minimum the number of any field joints. A flange or riveted connection shall be provided at the upper end of the liner for connecting the joint to the discharge ring or speed ring.

The liner plates shall be a minimum of five-eighth inch thick and shall be heavily reinforced on the outside with ribs of structural steel shapes for adequate anchorage to the surrounding concrete. Suitable jacks and anchors shall be provided to support the liner during erection and while being concreted in place.

A watertight mandoor with frame having an opening 24 inches wide by 36 inches high in the clear shall be provided and located in the liner to give access to the underside of the runner. The frame shall be securely fastened to the liner, and the door shall be flush with the interior surface of the liner. The door shall be hinged to swing outward and shall have bronze jackscrews, bronze hinge pins bronze-bushed and bronze bolts, and shall be fitted with one petcock for determining whether the draft tube is empty or not.

Sec. 33. *Turbine drains.*—Adequate provision shall be made for the collection of any water leakage occurring around the head cover, the stuffing boxes and other places subject to leakage, and its delivery to a point outside the pit liner or the speed ring for disposal by means provided by the Authority. Wherever water could collect in the head cover and below the floor plates, provision shall be made for filling recesses with concrete in the field during field erection.

A drain connection will be made at the low point of the scroll case for draining the scroll case to draft tube. The valve and drain piping grating and frame for this connection will be provided by the Authority.

Sec. 34. *Stairways, platforms, ladders, wrenches, and tools.*—The contractor shall furnish complete working, operating, and inspection platforms with stairs, handrailings, floor plates, and gratings in the turbine pit. All this equipment shall be designed for easy removal so that the turbine may be dismantled from above. Generator inspection platforms are specified separately and are not included in item 1.

The contractor shall furnish one complete set of case-hardened wrenches, special tools, special lifting tackle, and equipment necessary for the erection and dismantling of all parts of the turbine. The wrenches and tools shall be mounted on a neat plate-steel wrench board with marking to identify each tool.

ITEM 2. GOVERNING SYSTEMS

Sec. 35. *Description.*—The contractor, under item 2, shall design, furnish, and deliver three complete oil-pressure governing systems for controlling the speed of the turbines. The governing systems shall be of the relay valve "actuator" type with motor-driven governor heads, complete with auxiliary control mechanism, restoring mechanism, oil-pressure system, instruments, gauges, and accessory equipment and supports, as hereinafter specified and necessary for three complete governing systems.

The essential governing mechanism for two of the turbines shall be mounted in one cabinet with the hand controls and certain instruments and gauges on its faces. The twin cabinet shall be located on the operating floor between the two units with the front or operating face toward the upstream approximately as shown on the Authority's drawings.

The governing mechanism for the third turbine, including two oil-pumping units, shall be located in a single cabinet located similarly with respect to its generating unit.

Since the units will be controlled from a remote point, the governor shall be provided with such automatic devices as necessary to be operated by the remote-control system selected.

This automatic equipment shall include necessary starting solenoids, timing devices, automatic generator brakes, automatic shut-down devices, automatic turbine gate-locking device, and automatic shut-off valves.

The main valves shall be provided with adjustable stops which can be set and locked so as to limit the opening of the valves and thus control the rate of motion of the wicket gates.

The pressure tanks for the governor shall be located on the floor directly behind the governor cabinets.

SEC. 36. *Capacity of governing systems.*—The governing systems shall be designed for operation with oil pressure varying from a maximum of 300 psi to a minimum of 250 psi. The systems shall govern the speed of the turbines under fluctuating commercial load conditions within the limits of regulation and within the degree of sensitivity guaranteed by the contractor, and with each supplying a separate load, its system shall operate without causing hunting of the turbine gates and without causing changes or swings to the load.

With oil pressure of 250 psi, each governing system shall be adequate to operate the gate servomotors of each turbine through a full stroke, either opening or closing in 4 seconds.

The systems shall include equipment of relative capacities not less than the following:

Sump tank, ratio of volume (gal.) to volume of pressure tank (gal.)	0.6
Oil pump, ratio of capacity (gpm.) to volume (gal.) of servomotors	3.3
Pressure tank, ratio of volume (gal.) to volume (gal.) of servomotors	20

Governing Mechanism

SEC. 37. *Governor actuators.*—The components parts of each actuator shall be mounted on a base formed by the top of its sump tank.

Each actuator shall be enclosed in a cabinet of rigid construction. The operating handles or wheels, gauges, and instruments shall be mounted on the face of the cabinet, arranged as specified in section 61. The cabinet shall be properly ventilated and shall be dustproof.

The equipment within each cabinet shall be readily accessible for adjustment or for replacement of parts, and adequate doors shall be provided in each cabinet for access.

Positive control of the time of opening or closing the turbine gates shall be provided. This control shall be adjustable so that the time of opening or closing may be varied between four and twelve seconds for full stroke. The control shall be such that no action of the flyball control, control solenoids, load limit, or other devices can cause a gate movement faster than that for which the control is set. The gate servomotors will have a throttling device to slow down the movement of the gates as they approach the closed position.

Provision shall be made for the application of automatic synchronizing and of automatic load and frequency control, such as manufactured by the General Electric Co. or Leeds & Northrup Co.

The equipment of each actuator shall include the parts specified in the following sections 38 to 51, inclusive.

SEC. 38. *Governor head.*—The speed-responsive element of the governing mechanism shall be a set of flyballs driven by a direct-connected a.c. motor, assembled as a unit with the other governing mechanism in the cabinet. The speed of the flyballs shall vary in direct proportion with the speed of the main generator shaft and shall not be affected by ordinary variations in voltage or current of the main generator or of its exciters. The source of power for driving the flyball motor shall be either an independent self-exciting a.c. generator or potential transformers connected to the main generator terminals.

If the source of power for driving the flyball motor is an independent self-exciting a.c. generator, it shall be furnished complete and arranged for mounting above, and shall be direct-coupled through a suitable flexible coupling to the shaft of the main generator. The connection shall be such that in com-

bination with the electric tachometer an indication will be given when the turbine starts to rotate and just prior to its coming to a dead stop. This flyball generator shall be completely enclosed in a suitable housing with the overspeed and tachometer devices and shall be carefully insulated from the main turbine and generator to prevent stray currents.

The contractor shall cooperate with the generator manufacturer to design a proper arrangement for mounting the flyball generator and for its connection to the shaft.

If the source of power for driving the flyballs is potential transformers connected to the generator terminals, the contractor shall supply these transformers and fuse blocks. They shall be General Electric potential transformers type JE, or equal, and General Electric fuse blocks type ES-1, or equal, with a standard voltage ratio of 13,800 to 115.

The contractor shall furnish complete information and data regarding these transformers and connection. With the potential transformer drive, the contractor shall furnish 3-ph. low-voltage relays and such protective devices as may be required in connection with this type of flyball drive.

Sec. 39. *Gate- or load-limit device.*—This device shall be manually operated at the actuator and electrically operated by a split field motor controlled from the switchboard and shall include two indicators of the duplex type, each showing both gate-opening and load-limit setting. One indicator shall be furnished and mounted by the contractor on the cabinet. The other shall be furnished by the contractor and will be mounted by the Authority on the switchboard. The indicator mounted on the cabinet shall be equipped with two potentiometers for operating the remote indicators, one for the gate opening and one for the load-limit setting. The potentiometers will serve also for telemetering. A control switch for the split field motor will be provided on the switchboard by the Authority.

Sec. 40. *Synchronizing or speed-level device.*—This device shall be manually operated at the actuator and electrically operated by a split field motor controlled from the switchboard. Two indicators shall be furnished and one shall be mounted on the cabinet by the contractor; the other shall be mounted on the switchboard by the Authority. The indicator mounted on the cabinet shall be equipped with a potentiometer for operating the indicator on the switchboard. The potentiometer may also be used for telemetering. The speed-level control shall function to adjust the speed of the turbine from 85 percent of rated speed to no load and zero speed droop, to 105 percent of rated speed at full load and maximum speed droop.

The design of this device shall be such that when the turbine is operating at rated head, one electrical impulse of 1-second duration from the controller to the split field motor will produce a gate movement equivalent to approximately 1,000 kw. The manual control shall be so arranged that a gate movement equivalent to approximately 2,000 kw is obtained for each revolution of the control knob or handwheel.

A control switch for the split field motor will be provided on the switchboard by the Authority.

Sec. 41. *Automatic shut-down.*—The automatic shut-down device shall operate in response to the various protective devices and to emergency switches, at the actuator and at the main switchboard, to shut down the turbine. The automatic device shall also provide for closing the turbine gates to the speed-no-load position in response to the overspeed switch and shall reset automatically upon restoration of the overspeed switch to its normal position. At the option of the contractor a separate speed-no-load device may be provided.

The devices shall function through the deenergizing of one or more normally energized solenoids operated by 250-v. d.c. circuits.

A shut-down and reset switch shall be provided on the cabinet and when the unit has been shut down by this means resetting shall be possible only by restoring the switch to the "normal" position.

Sec. 42. *Electric tachometer.*—The electric tachometer shall be suitably driven from the main shaft of the generator and insulated against stray currents. Two suitable indicating instruments shall be furnished. One shall be mounted by the contractor on the cabinet, and one shall be mounted on the switchboard by the Authority.

SEC. 43. *Overspeed device.*—The overspeed device shall be suitably driven from the main shaft of the generator and shall function to shut down the turbine to speed-no-load and to sound an alarm at a predetermined overspeed. resetting automatically at 105 percent of normal speed. It shall be insulated to prevent short circuits and shall operate through three single-pole, 3-amp., 250-v., d.c., ungrounded switches, changeable from circuit opening to circuit closing, one in the turbine shut-down circuit, one in the unit shut-down circuit, and one in the alarm circuit. The Authority will provide the alarm. The overspeed device shall be insulated to prevent stray currents.

SEC. 44. *Speed droop adjustment.*—The device shall be designed for manual adjustment at the actuator. It shall be equipped with an indicator showing the percentage of droop employed. The range of adjustment of the speed droop device shall be from zero to 6 percent droop from zero to full gate opening, respectively.

SEC. 45. *Auxiliary switches.*—A 5-pole, 250-v. switch shall be furnished and shall function to close or open each pole at any desired gate opening. Each pole shall be electrically separate and adjustable as to gate opening.

A single-pole switch shall be provided to open the "raise" circuit of the split field motor of the synchronizing device when the gate position indicator comes up to the setting of the load-limit device. Each switch shall be 3 amp., 250 v., d.c., ungrounded.

The gate-limit device shall operate a 5-pole auxiliary switch and two 5-pole, gate-position, 3-amp., 250-v., d.c., ungrounded, interlock switches to be used for the control of circuits provided by the Authority. The operation of each switch shall be adjustable as to make and break and as to position.

SEC. 46. *Manual control.*—Means shall be provided at the actuator for manual control of the turbine gates using the oil-pressure system. A convenient change-over device shall be provided to switch from governor to manual control and also to shut off the oil pressure. An indicator shall be furnished and mounted on the cabinet to show which control is engaged.

SEC. 47. *Generator air-brake control.*—An automatic brake-control mechanism shall be provided which will apply the brakes intermittently when the turbine is being shut down. This mechanism shall be adjustable as to delay before application and number of intermittent applications. In addition, a manual control switch shall be furnished for the generator air brakes. It shall be mounted on the governor cabinet and shall be manually operated without actuating the automatic device. For the unit there shall be provided two 250-v. single-pole pressure switches, one of which shall operate to sound an alarm (provided by the Authority) if the brakes should be applied when the turbine gates are open and the generator is connected to the line; the other shall operate to sound an alarm (also provided by the Authority) if the air pressure in the supply system is low. The control manual switch handle shall be pistol-grip type.

SEC. 48. *Air-brake gage.*—A gage of the duplex indicating type, graduated in pounds per square inch to indicate the air pressure on the supply system and also in the brake cylinders, shall be furnished and mounted on the cabinet.

SEC. 49. *Oil-pressure gage.*—A pressure gage to indicate the pressure in pounds per square inch in the oil-pressure tank shall be furnished and mounted on the cabinet.

SEC. 50. *Oil-pressure switches.*—Three pressure switches shall be furnished. one for actuating the shut-down mechanism, one for starting the interlock circuit, and one for the alarm circuit when the oil pressure drops to a predetermined point. Each switch shall have one adjustable, 3-amp., 250-v., d.c., ungrounded contact.

SEC. 51. *Wiring of actuator and cabinet.*—The contractor shall furnish and completely install all electrical wiring connecting the apparatus within and on the actuator and the cabinet, bringing all terminal connections to terminal blocks so located with the cabinet as to be readily accessible for making external connections in the field. All wiring shall be so located as to be conveniently accessible for maintenance and repair.

No wire shall be smaller than No. 12 Awg. All wires shall have 600-v., varnished cloth, asbestos, flameproof insulation. All terminal blocks shall be General Electric Co. type EB, or equal, and those for the annunciator shall provide approximately 24 terminals. Wiring diagrams for connections to the annunciator will be provided by the Authority.

Suitable lighting and light switches shall be provided for the interior of the cabinet.

Oil supply systems for governors

SEC. 52. *Description of systems.*—The contractor shall furnish a complete oil system for supplying oil to operate the gate servomotors. The system shall include two motor-driven pumps, pressure tank, sump tank, and accessory parts, and all necessary piping.

The two oil pumps mounted in the cabinet shall be interconnected so that either pump can be used under normal operating conditions with the other pump shut down but automatically coming into operation if the oil pressure in the pressure tank falls to some predetermined point below that at which the first pump is set to start. The interconnection shall be provided with suitable stop valves and designed so that either pump can be dismantled while the other is operating.

Provision shall be made so that each of the two pumps can be operated by "start" and "stop" control, or the pump operated continuously, loading and unloading as demanded by the oil-pressure requirements.

SEC. 53. *Governor oil pumps.*—The pumps shall be of the motor-driven, self-priming, positive-displacement type, each having a capacity against 300-pound pressure of not less than that specified.

Each motor shall be direct-connected to its pump and shall be of 440-v., 3-ph., 60-cycle, 40° C., squirrel-cage, low-starting current, induction type, designed for full-voltage starting and conforming to NEMA and AIEE standards. Capacity, speed, and torque shall be suitable for the pump requirements. The motor shall have open frame, enclosed terminal box, insulation impregnated against moisture and oil, and ball or roller bearings in dustproof housings with adequate means of retaining the correct amount of lubricant.

An automatic control shall be furnished for each motor which will start the pump when the pressure in the pressure tank drops to a predetermined minimum and will stop the pump when the oil pressure rises to a predetermined maximum. This control shall be arranged so that the pump will reach full speed before it loads and will unload before the motor is disconnected from the power supply.

The oil pumps shall be mounted within the cabinet. Ventilation shall be provided, sufficient to carry away the heat occasioned by the operation of the pump motor.

The contactor or magnetic starting switch for the pump motors of the governor will be furnished by the Authority and mounted on the auxiliary unit board. The manual control switch for the pump motors shall be furnished by the contractor and shall be mounted on the cabinet. The individual pressure switches, furnished by the contractor, shall be for 460-v. a.c., and means shall be provided so that the operating range of the pump may be readily adjusted. Indicating lamps shall be provided and mounted on the face of the cabinet to show when the pump is operating or ready to operate.

SEC. 54. *Governor tanks.*—The contractor shall furnish a pressure tank of welded steel construction equipped with a graduated oil-level sight glass having both manual and automatic shut-off cocks and guarded to prevent breakage, air-blow-off valve, manhole, oil drain, suitable compressed air connection, and connections for the oil piping.

All connections, except for the blow-off valve, the compressed air connection, and the top connection of the gauge glass, shall be made below the oil level. Provision shall be made to prevent the oil level being lowered sufficiently to allow air to blow into the piping system.

The contractor shall furnish a sump tank of welded steel construction, equipped with gauge glass, manhole, strainer through which all oil returning to the tanks shall pass, and connections for filling, emptying, or filtering.

The capacity of the pressure tank and of the sump tank shall be as specified in section 36. The pressure tank shall be constructed and tested in accordance

with the ASME Boiler Construction Code, section VIII, paragraphs U69, U76, U77, and other applicable paragraphs, for Unfired Pressure Vessels.

SEC. 55. *Governor piping.*—The contractor shall furnish all unloading valves, check valves, safety valves, and other types of valves, and all pipe and fittings for the connections between the pumps, pressure tank and sump tank, actuator, turbine servomotors, and any equipment furnished by him.

So far as practicable all piping shall be assembled by the contractor before the governor is shipped. Oil piping shall be of such size that the maximum velocity of oil flow therein shall not exceed 18 feet per second.

The entire piping system shall be fusion-welded in accordance with the American Standards Association Code for Pressure Piping B31.1–42 and subsequent supplements, applicable paragraphs, except for such flanged joints and connections as may be necessary for erection or subsequent dismantling. So far as practicable all welding shall be done in the shop.

Pipe shall be seamless steel tubing of size and thickness of wall required by the service and shall be scale free, and the interior surface shall be thoroughly cleaned by sandblasting or pickling. Flanged connections shall be made with welded Van Stone flanges, or equal.

Flanges and ends shall be properly protected for shipment.

Valves, except those built into or forming a part of a governor or pumping unit, shall be steel-body, bronze-mounted, extra-heavy solid-wedge type, with bronze rising stems. Bolts shall have semi-finished heads and nuts, and finished washers if their location requires.

Long-radius pipe bends having smooth surfaces shall be used in place of fittings wherever practicable, and fittings if used shall be of the long-sweep type.

Switches, gages, and instruments

SEC. 56. *Accessories furnished and mounted by contractor.*—The contractor, under item 2, shall furnish and mount on the cabinet for the governor the following instruments and switches:

1—Annunciator reset switch.
1—Annunciator test switch.
1—Set of contact switches with indicating lights for the turbine bearing d.c. and a.c. oil pumps.
1—Switch for generator housing heaters.
1—Leeds and Northrup Micromax 16-point temperature recorder with two alarm contacts for use with 10 ohms at 25° C. resistance temperature detectors 0°–150° C. range; 110-v. 60-cycle, synchronous motor drive, 10-inch chart with chart speed of 1⅜ inches per hour. Temperature recorder to be mounted flush or semiflush.
1—Pressure gauge for indicating pressure on generator cooling water supply, scale 0 to 100 feet of water.
1—Three-pen Taylor mercury-actuated recording thermometer, or equal, with not more than 75 feet of temperature compensated tubing, scale 0° to 50° C. for generator cooling water inlet and discharge and thrust bearing discharge.
1—Synchronous clock, 8-inch dial, 115-v., 60-cycle motor. (Only two clocks required, one on each governor cabinet.)
1—Duplex pressure gauge to indicate forebay water pressure and scroll case water pressure, calibrated in feet of water, scale 0 to 200 feet.
1—Indicating and totalizing flowmeter of ring balance construction designed for full-scale deflection with a differential of 20 to 140 inches of water, to be connected to taps in the scroll case to measure the flow through the turbine, the calibration to be made after field tests.

The following instruments will be furnished by the generator manufacturer and shall be mounted on the cabinet by the contractor:

1—Guide bearing indicating thermometer with high-temperature alarm contact.
1—Thrust bearing indicating thermometer with high-temperature alarm contact.
1—Remote oil-level indicator for thrust bearing oil reservoir.

SEC. 57. *Accessories furnished by the Authority for cabinet mounting.*—The contractor, under item 2, shall mount on the governor cabinet the following accessory equipment to be furnished by the Authority:

1—Flush-mounted annunciator cabinet approximately 26 inches wide, 6½ inches high, and 8 inches deep.
1—Signal cabinet approximately 15 inches wide, 6½ inches high, and 11 inches deep.
1—Switch for control of carbon-dioxide fire-protection system.

One hand telephone set and one telephone jack will be furnished by the Authority and shall be mounted on the cabinet.

SEC. 58. *Accessories furnished by contractor for switchboard mounting.*—The contractor, under item 2, shall furnish the duplex gate opening and load-limit indicators specified in section 39 and the tachometer indicators specified in section 42, but the Authority will mount these instruments in the appropriate place on its switchboard.

SEC. 59. *Turbine gauges.*—The contractor, under item 1, shall furnish for the turbine the following gauges and devices, and the contractor, under item 2, shall mount the gauges and indicators on the governor cabinet except as otherwise provided:

a. One combined pressure and vacuum gauge, to indicate pressure or vacuum in the draft tube, to be mounted adjacent to the draft tube mandoor.

b. Two turbine guide bearing thermometers with high-temperature alarm contact.

SEC. 60. *Type and arrangement of instruments.*—All instruments, gauges, indicators, and control switches furnished by the contractor shall be of standard switchboard size, type, and finish. Before purchase, the contractor shall submit to the engineer for approval complete data covering them.

All control switches shall be Westinghouse Electric Corp. type W or General Electric Co. type SB, or equal. All indicating lamps shall be standard switchboard indicating lamps, with 1⅜-inch-diameter color caps and resistors. All equipment and wiring shall conform to the standards of the AIEE and NEMA.

The gauges, instruments, and controls on the face of the cabinet shall be mounted on removable panels of the cabinet as directed by the engineer. Electrical controls, switches, and instruments shall, insofar as possible, be mounted on swinging panels.

The various parts on the panel shall be arranged in a neat and orderly manner.

Each instrument shall be provided with a neat label indicating its purpose or use.

Each instrument shall be provided with antiglare glass as manufactured by the General Electric Co., or equal.

Each instrument shall be designed and arranged so that the glass may be removed without removing the instrument from the governor panel.

Motor-driven air compressor

SEC. 61. *Type and rating.*—The contractor, under item 2, shall furnish one air compressor of the motor-driven, 2-stage, 2-cylinder, air-cooled type, with air-cooled intercoolers and aftercoolers having a capacity of not less than 8 cubic feet of free air per minute (actual, not by displacement) against 300-pound gage pressure, complete with all piping, electrical connections, motor controls, and accessories. The compressor will be used for building up pressure in the oil-pressure tank of the governor.

The compressor shall be equipped with an unloading device which will unload the compressor to atmosphere whenever the motor stops and maintain this condition until the motor is running at full speed. It shall also be equipped with a start-stop pressure control switch, a pressure relief valve, and a receiver pressure gauge.

The motor and compressor shall be mounted with a pressure tank. This entire unit will be located outside of the actuator cabinet by the Authority. Suitable piping and valves will be provided by the Authority to connect the air compressor to the oil-pressure tank.

The motor starter shall be of the magnetic type with thermal overload and undervoltage protection, operated by a push button located on or near the compressor assembly.

SEC. 62. *Motor.*—Motor shall be 440-v., 3-ph., 60-cycle, squirrel-cage, induction type, conforming to the AIEE and NEMA standards. It shall be sized for

starting at rated voltage and for continuous operation at full load with a temperature rise not exceeding 50° C. Windings shall be impregnated to withstand moisture and braced to withstand starting stresses. The motor shall have ball bearings, splashproof frame, adjusting rails, and enclosed conduit terminals.

SHOP ASSEMBLY, CLEANING, AND PAINTING

SEC. 63. *Shop assembly.*—Before shipment, the parts of the equipment furnished under this contract shall be assembled in the shop as follows.

Turbine

The runner and shaft shall be fitted together and the guide bearing fitted to the shaft.

The draft tube liner shall be assembled with the throat or discharge ring. The scroll case shall be assembled with the speed ring.

The pit liner, speed ring, and discharge ring shall be assembled together.

The head cover, guide bearing, stuffing box, bottom plate, gates, gate-operating mechanism and related parts shall be assembled together with the embedded parts, if practical.

If it becomes necessary to ship the embedded parts before completion of the other parts, the head cover shall be fitted to the speed ring and the bottom plate to the discharge ring or speed ring. The head cover, bottom plate, and remaining turbine parts shall be assembled together with suitable temporary spacers or supports provided to hold the parts in their proper relative positions.

While assembled, parts shall be match-marked, and the upstream-downstream and transverse center lines shall be accurately scribed on the horizontal flanges and center punch-marked on the sides to facilitate proper erection in the field.

Connections between parts shall be shop-doweled if practical, or rough-drilled for field doweling.

Governor

The governor shall be completely assembled in the shop. The oil pumps shall be operated at specified capacity and pressure, and the governor head operated.

The assembly of turbine and of governor will be inspected and checked by the engineer and all check measurements recorded for comparison with like measurements to be made in the field. Any errors, interferences, or faulty material or workmanship discovered by the engineer shall be promptly corrected by the contractor.

SEC. 64. *Shop cleaning and painting.*—After shop assembly and inspection, parts of the turbine and governor shall be cleaned and painted as follows.

All surfaces shall be cleaned of all loose scale, rust, dirt, oil, grease, or other foreign matter, employing such means as may be necessary to clean effectively without injuring the surfaces.

Surfaces to be in contact with concrete as identified on the contractor's drawings and a band 4 inches wide on either side of a field-welded joint shall not be painted.

Unfinished surfaces to be in contact with oil, except piping, shall be painted two coats of approved oilproof enamel. Other unfinished surfaces shall be painted with one coat of underwater gray paint.

Finished surfaces of parts made of ferrous metals shall be coated where practicable with white lead and tallow or other approved slushing compound.

The governor cabinet shall be coated with approved enamel of a color as directed by the engineer.

MATERIAL SPECIFICATIONS

SEC. 65. *Cast iron.*—Cast iron shall meet the requirements of the American Society for Testing Materials, Standard Specification for Gray-Iron Castings for Valves, Flanges and Pipe Fittings, designation A126–42, class B.

SEC. 66. *Steel castings.*—Steel castings shall be of quality equal to that required by the American Society for Testing Materials, Standard Specification of Carbon-Steel Castings for Miscellaneous Industrial Uses, designation A27–46T, grade 65–35 or 70–36.

SEC. 67. *Steel plates.*—Steel plates, except as otherwise specified, shall conform to the American Society for Testing Materials, Standard Specification of Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels, designation A285–47, Flange or Firebox Quality, grade B.

Rivets except as otherwise specified shall conform to the American Society for Testing Materials, Standard Specification for Boiler Rivet Steel and Rivets, designation A31–40, grade A.

SEC. 68. *Corrosion-resisting steel.*—Corrosion-resisting steel (sheet, strip, and plate) shall meet the requirements of the specification of the American Society for Testing Materials, designation A176–44, grade 4, type 430, except where the use of other alloys may be approved for special purposes, and except that grade 2, type 410, may be used for wearing plates specified in section 29.

SEC. 69. *Bronze castings.*—Bronze castings shall be of a quality equal to that required by the specification of the American Society for Testing Materials, designation B143–48. Bronze bearing bushings shall be of a quality equal to that required by the specification of the American Society for Testing Materials, designation B22–47T, class C.

SEC. 70. *Noncorrodible bolts and nuts.*—Bolts and nuts shall be made of stainless steel or bronze when used under the following conditions:

> Throughout the work when bolts or nuts, or both, are subject to frequent adjustment or removal, such as adjusting bolts for gland rings of stuffing box, manhole bolts, bolts or mandoors, removable screens, strainers, and adjustable bearings.

The materials shall have free-machining qualities and be suitable for heading in a bolt machine.

Bronze for bolts and nuts shall be of quality equal to that required by the American Society for Testing Materials, Standard Specification for Naval Brass Rods, Bars, and Shapes, designation B21–48T, grade A or B.

TESTS

SEC. 71. *Acceptance tests.*—Within 18 months after receipt of the equipment, the Authority may make such tests as it considers necessary to determine whether or not the contractor's guarantees have been fulfilled and whether or not the turbine has the capacity specified. The Authority will notify the contractor sufficiently in advance of each test so that he may have a representative present.

Prior to the tests, the interior of the turbine will be inspected by the Authority and the contractor. Should such inspection disclose that any damage or wear has taken place, the Authority will repair such damaged or worn parts before the test unless such damage or wear is due to failure of the contractor to meet the requirements of the contract or is due to cavitation.

The efficiency of the turbine will be determined from the power output, the net head, and the quantity of water flowing through the turbines.

ITEM 3. SPARE PARTS

SEC. 72. *Spare parts.*—Under item 3 the contractor shall furnish and deliver one set of the following spare parts for the turbine:

a. One complete set of wearing parts for a turbine guide bearing.

b. Three gate stem levers or arms with links.

c. One complete set of breaking pins or links for the gate-operating mechanism.

Spare parts shall be interchangeable with and of the same material and workmanship as the corresponding parts of the turbine.

ITEM 4. CHANGE IN LENGTH OF SHAFT

SEC. 73. *Price adjustment for change in turbine shaft length.*—If the length of the pit liner be changed from that specified in section 7, there shall be added to or deducted from the contract price for item 1, as the case may be, for each foot of increase or decrease the corresponding contract price for item 4 with fractional parts thereof for fractional parts of a foot.

ITEM 5. CHANGE IN LENGTH OF PIT LINER

SEC. 74. *Price adjustment for change in length of pit liner.*—If the length of the pit liner be changed from that specified in section 7, there shall be added to or deducted from the price for item 1, as the case may be, for each pound of metal added to or deducted from the pit liner the corresponding contract price for item 5.

ITEM 6. GENERATOR INSPECTION PLATFORM

SEC. 75. *Generator inspection platform.*—Under item 6 the contractor shall furnish and deliver a suitable platform for access to the lower parts of the generator. The platform shall be capable of supporting a half thrust bearing runner. It shall be located in the turbine pit and shall be supported from the generator bearing bracket or from the turbine pit walls. It shall be designed so as to be readily removed to allow dismantling the turbine from above.

Suitable provision shall be made for access to the inspection platform, either by a stairway or ladder from the turbine deck or from the entrance stairs.

DATA TO BE SUBMITTED WITH BID

Bidder's specifications and drawings.—Each bidder shall submit with his bid complete specifications and general drawings describing and illustrating the equipment he proposes to furnish. The information shall include all essential dimensions, the kinds of material to be used in each major part, with the chemical and physical properties of materials if other than those covered in detail in the Authority's specifications, and the following drawings and detailed data:

Turbine

1. General plans and sections showing all essential details of the proposed turbine settings, including all water passages.
2. General drawings of the turbine showing:
   a. Diameter of main shaft.
   b. Outside diameter of sleeves on main shaft.
   c. Diameters of wicket gate stems.
   d. Diameter of wicket stem bearing circle.
   e. Diameter of runner.
   f. Main guide bearing.
3. Outline drawing of the draft tube showing piers.
4. Outline drawing of the speed ring and scroll case showing principal dimension.
5. Test curves of a homologous model turbine runner tested with draft tube similar to type proposed. These data shall include curves for unit horsepower, unit discharge and efficiency plotted against sigma for the full range of heads as specified for this plant, and curves for unit horsepower, unit discharge and efficiency plotted against unit speed. These data shall cover the full range of gate opening. There shall also be furnished with the above data the name of at least one plant where a turbine homologous to the test runner is in operation giving the rated head, full gate horsepower, and rated speed. Bids not accompanied by these data may be rejected.
6. Estimated capacity and efficiency curves for the turbine when operating at the specified speed and under the heads at which the bidder's guarantees are made. Guaranteed performance points shall be clearly indicated.
7. Method of dismantling turbine, with necessary dimensions to determine conformance with crane clearances.

Governor

8. Description and drawings of the governor showing:
   a. General arrangement and dimensions of the proposed equipment.
   b. Illustrations or drawings showing the construction and arrangement of the actuator, the oil pumps and motors, the tanks and piping.
   c. Description of the method of driving the flyball motor.
   d. Description of the method used for remote control and remote indication of the governor controls.

e. Illustration or drawing showing the proposed arrangement of the instruments and controls to be mounted on the face of the actuator and cabinet with a list of such instruments and controls.

PHYSICAL DATA

Each proposal shall contain at least the following physical data:

Turbine Data

Maximum runaway speed at maximum head	________
Flywheel effect of rotating parts, lb.-ft.[2]	________
Dimensions of gate servomotor cylinders, inches	________
Volume of two gate servomotor cylinders, cubic inches	________
Size of pipe connections to gate servomotor cylinder, inches	________
Total net weight, pounds	________
Net weight of rotating parts, pounds	________
Hydraulic thrust at maximum head and normal speed, pounds	________
Hydraulic thrust at maximum head and runaway speed, pounds	________
Weight of rotating parts plus hydraulic thrust at maximum head and normal speed, pounds	________
Diameter of runner at discharge, inches	________
Diameter of runner at centerline distributor, inches	________

Governor Data

Make, type and size	________
Source of power for flyball drive	________
Minimum capacity of governor, ft.-lb. per second	________
Oil pump:	
Manufacturer	________
Type	________
Speed, r.p.m	________
Minimum capacity against 300-pound-per-square-inch gauge pressure, g.p.m.	________
Oil pump motor:	
Manufacturer	________
Type	________
Rating, h.p.	________
Speed, r.p.m.	________
Overall dimensions of oil pump and motor ____X____X____	________
Tanks and piping:	
Volume of pressure tank, cubic feet	________
Overall dimensions of pressure tank	____X____X____
Volume of sump tank, cubic feet	________
Overall dimensions of sump tank	____X____X____
Size of oil piping for servomotors, inches	________
Maximum velocity of oil in piping to servomotors, feet per second	________
Type and quantity of oil for the governor system	________
Actuator cabinet:	
Overall dimensions, twin cabinet	____X____X____
Overall dimensions, single cabinet	____X____X____

TURBINE CAVITATION GUARANTEES

The undersigned bidder hereby guarantees that excessive cavitation will not occur in the runner of the turbine within one year from the date the turbine is placed in commercial operation provided that the turbine is not operated (see section 19):

1. More than 800 hours during the year at less than the minimum horsepower specified below or

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2. More than 50 hours during the year at outputs greater than the maximum specified below.

Output horsepower Minimum	*Output horsepower* Maximum	*Net head, feet*
		120
		110
		100
		90
		80
		70

The centerline of the distributor will be set at elevation 1272 or 8 feet above tailwater with a discharge of approximately 4,000 c.f.s. through the unit.

TURBINE CAPACITY AND EFFICIENCY GUARANTEES

The undersigned bidder hereby guarantees that when operating at a speed of 100 r.p.m. the turbine shall have capacities and efficiencies of not less than those set forth in the following tabulation for the net heads specified:

Net head, feet	Maximum horsepower capacity guaranteed	Guaranteed efficiency at					
		Maximum horsepower guaranteed	34,500 hp.	30,000 hp.	25,000 hp.	20,000 hp.	10,000 hp.
120							
110							
100							
90	34,500						
80							
70							

Leave efficiency guarantees blank when maximum horsepower capacity guaranteed is less than horsepower listed.

GOVERNOR PERFORMANCE GUARANTEE

The undersigned bidder hereby guarantees that when operating under a sustained isolated load the magnitude of the sustained speed oscillation caused by the governor will not exceed 0.3 of 1 percent of rated speed with speed droop set at or above 2 percent, and that the dead band at rated speed shall not exceed 0.06 percent of the rated speed at any load. He also hereby guarantees that the performance of the governor will be such that upon sudden changes of load on the turbine and with movement of the turbine gates no faster than that specified, the speed change will be not greater than the following:

Load change, percent of rated capacity	*Speed change, percent*
Load on	
10	
25	
50	
Load off	
10	
25	
50	
100	

Above is based on a governor closure rate of 6 seconds and on a total WR^2 of 36,000,000 lb.-ft.^{2} for the revolving parts of the unit and a normal speed of 100 r.p.m.

SPECIFICATION NO. 3449, TWO 132-INCH TURBINE INLET VALVES FOR WATAUGA PROJECT

(Reference drawings not included in this report)

SECTION 1. *Scope of Work.*—The work covered by this specification comprises designing, furnishing, and delivery to Elizabethton, Tennessee, the following equipment:

Item 1. Two 132-inch butterfly valves, complete with operating mechanism, controls, and safety devices, *or*

Item 1a. Two 132-inch pivot valves, complete with operating mechanism, controls, and safety devices.

The attached preliminary drawing No. 47W905RO entitled "Turbine Inlet Valve—Alternate Arrangements" shows the general arrangement and setting for which the valves are intended. The Authority will install all equipment to be furnished under this specification.

SEC. 2. *Drawings to be furnished by the contractor.*—The contractor shall furnish for approval six prints of assembly and detail drawings in such detail as necessary for installation, operation, and maintenance of the equipment and for demonstrating that it complies with the requirements of the specifications. All drawings and data shall be identified clearly by serial numbers and descriptive titles indicating their application to the contract.

The drawings and data furnished by the contractor shall include:

a. Detail and arrangement drawings of the equipment in elevation and plan, giving all important dimensions, locations, and size of all connections, etc.

b. Cross-sectional drawings of the complete equipment, showing all parts for identification.

c. Outline and dimension drawing showing method and sequence of erection and operation.

d. Wiring diagrams and schematic diagrams for all electrical equipment.

Any work done or materials ordered by the contractor prior to his receipt of drawings approved by the engineer shall be at the contractor's risk.

Upon approval of all drawings by the engineer, the contractor shall furnish six additional copies of a to d inclusive above for the Authority's permanent files.

SEC. 3. *The engineer.*—Work under this specification shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the Engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specification.

SEC. 4. *Materials of construction.*—Materials of construction shall be in accordance with the following:

a. *Cast iron.* Cast iron shall meet the requirements of the American Society for Testing Materials standard specification for gray-iron castings for valves, flanges, and pipe fittings, designation A126–42, class B.

b. *Steel castings.* Steel castings shall meet the requirements of the American Society for Testing Materials standard specification for carbon-steel castings for miscellaneous industrial uses, designation A27–44, grade B1 or B2, full annealed.

c. *Steel plates.* Steel plates shall meet the requirements of the American Society for Testing Materials standard specification for carbon-steel plates A70–44, A201–44, or A78–43, firebox or flange quality. Steel plate not subject to operating or hydraulic stresses may be of commercial grade.

d. *Alloy castings.* Alloy castings shall meet the requirements of the specification of the American Society for Testing Materials, designation B143–44T for bronze castings or B62–44 for brass castings.

DETAILED SPECIFICATIONS

SEC. 5. *General.*—Each valve will be used as an open or shut valve in the penstock line immediately upstream of the turbine scroll case inlet and will handle gravity flow of screened raw river water. The valve will be set with its axis horizontal and will be subjected to a maximum static pressure above the horizontal center line of 325 feet. The valve shall be capable of closing in approximately 300 seconds with a flow of 1500 cfs, with headwater at the maximum point of 325 feet above the center line, without straining, slamming, or chattering. When opening, the pressure on each side of the valve disc will be practically balanced. The valve shall be designed so that an operating pressure of 210 pounds per square inch will result in a unit stress of not more than two-thirds of the yield point stress as indicated by the ASTM specification for the various metals, except that for cast iron the maximum allowable stress shall not exceed one-fifth of the ultimate stress.

The contractor shall furnish all foundation anchor bolts.

SEC. 6. *Valve body.*—The valve body shall be of cast- or welded-steel construction and shall have a clear opening of 132 inches in diameter. The connections between the valve body and the penstock shall be designed for riveting. The design of this joint shall be made in cooperation with the Authority. The rivet holes in the valve shall be drilled full-size and the manufacturer shall furnish sufficient rivets for the connections. The Authority desires that the valve body length be held to a minimum. Present clearances dictate that this dimension be not more than 7 feet 3 inches, overall, but a slight increase in this dimension may be accepted if the valve design precludes a shorter dimension.

The valve body shall be designed to permit removal of valve disc and shaft. If the body is split, the connection between the two halves shall be designed for bolting. Bronze bushings and stuffing boxes for each end of the pivot shaft shall be provided in the valve body. The bronze bushings shall have a Brinell hardness of not greater than 110 and shall be shrunk in. Each bearing shall be designed for pressure grease lubrication. Lock-on-type alemite fittings and a portable hand-operated pressure grease gun shall be provided.

The valve body shall be drilled and tapped for the piezometer tube connections to the differential pressure switch.

The inside of the valve body shall be recessed and fitted with a stainless steel, bronze, or babbitt seal ring where the outside circumference of the disc fits against the housing when the disc is in the closed position.

The valve body shall be ribbed heavily and braced on the outside so that it will hold its shape under pressure. The interior of the body shall be smooth and streamlined to offer a minimum of resistance to the flow of water.

SEC. 7. *The pivot shaft and wicket gate.*—The pivot shaft shall be of forged steel and shall be provided with bronze sleeves having a Brinell hardness of not less than 150, shrunk on each end where the shaft passes through the bushing and the stuffing boxes in the valve body.

The wicket gate or disc shall be of cast- or welded-steel construction securely keyed to the shaft.

The wicket shall be a good fit into the housing and shall be practically watertight under a static head if 325 feet. The valve shall be field-tested under a static head of not less than 250 feet, and the leakage shall not exceed that guaranteed by the contractor.

SEC. 8. *Operating and control mechanism.*—The wicket gate opening and closing mechanism shall be motor-operated gearing. The gears shall be of a substantial and rugged design and shall be cut from forgings or steel castings. The initial reduction may be made by steel worm and bronze gears. The initial reduction shall operate in oil, and its housing shall be oiltight and of rigid construction to prevent chattering. Provisions shall be made for manual operation of the wicket.

The Authority will provide a 6-inch hand-operated bypass valve and line around the main valve to permit filling the scroll case and balancing the pressure before opening the main valve. All connections for this bypass will be made in the penstock sections being furnished by the Authority. The Authority also will furnish a 3-inch vent valve on the penstock section immediately downstream from the main valve to release air from the scroll case during the filling cycle.

The 132-inch valve shall have a 250-v. d.c. motor, with weatherproof frame and with ball or roller bearings. The motor shall be equipped for full-voltage starting and of capacity, starting, and operating characteristics adequate and suitable for the purpose.

Suitable limit switches shall be provided to cut off the motor when the valve reaches the fully open or fully closed position. These shall include reversing braking controls and jam relays, all panel-mounted and complete with control relays and interlocks to deenergize the shunt field when the motor is idle. There also shall be provided for local surface mounting one (open-close-stop) 3-button push-button station.

A selsyn transmitter and two receivers shall be provided so that the position of the valve may be shown accurately on the control panels. The transmitter shall be driven positively from the operating gears. One indicating instrument will be mounted on the governor panel together with an emergency closing button. The other indicating instrument with an emergency closing button will be mounted in the main control board.

The receiving instruments will be mounted in cases to match cases on the control board and governor board and shall be subject to approval by the engineer.

A suitable differential pressure switch with all necessary piping, valves, and connections shall be furnished. It shall function to prevent the wicket gate from being opened when there is a differential of 2 pounds or more on opposite sides of the valve wicket under any head up to a maximum of 325 feet. The switch shall be for use with 250-v. d.c. and shall be equal to No. 848 Differential Pressure Control as manufactured by the Mercoid Corp., Chicago, Ill.

EQUIPMENT DATA

The undersigned bidder proposes to furnish equipment guaranteed to meet the requirements of TVA specification No. 3449 and to be in accordance with the following:

Type of valve	______
Minimum diameter of shaft, in.	______
Length of housing, F to F, in.	______
Percent clear area, valve open	______
Motor, hp	______
Motor, r.p.m	______
Motor, make	______
Closing time, sec	______
Type of reduction gear	______
Maximum leakage, guaranteed g.p.m., 250-foot head	______
Maximum leakage, guaranteed g.p.m., 325-foot head	______
Weight of heaviest piece	______
Overall size of biggest piece	______
Total weight of valve	______
Type pressure switch manufacturer's catalog and No	______
Diameter bolt circle	______
Number bolts	______
Size of bolts	______
Gasket material	______

NORRIS TURBINE ACCEPTANCE TESTS

Turbine acceptance tests, made during October 1937 on both power units, were conducted by means of the Gibson[1] method for measurement of water flow in closed conduits.

This method of water measurement is based upon the equation of impulse and momentum and affords a means of determining the steady-state discharge in closed conduits by taking a continuous photographic record of pressure rise

[1] Gibson, N. R., The Gibson Method, and Apparatus for Measuring the Flow of Water in Closed Conduits, Transactions, American Society of Mechanical Engineers, 1923. Thoma, D., Concerning the Degree of Accuracy of the Gibson Method of Measuring the Flow of Water, Transactions, American Society of Mechanical Engineers, 1935, Hyd-57-4. Gibson, N. R., and Strowger, E. B., Experimental and Practical Experience with the Gibson Method of Water Measurement, Transactions, American Society of Mechanical Engineers, Hyd-57-5.

with respect to time, following fairly rapid closure of the turbine gates. With the conduit dimensions known, the difference between the initial discharge and the leakage flow—which escapes when the turbine gates are completely closed—may be obtained from the pressure-time diagram. There are two alternate types of diagrams: the simple diagram in which pressure changes at one fixed cross section are recorded and the differential diagram in which the instantaneous difference between changes in pressure between two fixed cross sections in the conduit are recorded. The differential method was employed because of the slightly greater accuracy.

Tests made

The entire test was conducted under the provision of the Power Test Code of the American Society of Mechanical Engineers, Series 1926, except that all electrical instruments, including current and potential transformers, were not calibrated both before and after the test. Computation of turbine efficiencies required readings to determine the flow, net and gross heads, and power output at various gate openings. Readings on overspeed were also made.

Arrangement of equipment

For the Gibson apparatus two sets of four piezometers were installed in each penstock, as shown in figure 365, at a distance of 91 feet 10 inches apart. Pipe connections from each set of taps terminated at the walkway at the downstream face of the dam where the Gibson pressure-recording apparatus was installed.

The gross head on the turbine was measured by reading the reservoir and tailwater elevations. The tailwater elevation was determined by means of a float gauge, located in the powerhouse, which is a part of the regular operating equipment. Indication of the float gage level is transmitted to the control room by means of a standard selsyn motor arrangement.

Measurement of the net head on the turbine was made by means of a special water manometer constructed by the Authority. One leg of this manometer was connected to a pipe which led to four net head piezometers located a few feet downstream from the entrance to the scroll case. The other leg was connected to a pipe which led to piezometer No. 9, located in the reservoir on the upstream face of the dam. Compressed air, introduced in a header joining the top of both legs, depressed the water columns. The difference in height of the water columns represented the sum of the velocity head at the net head piezometer section and the loss of head from the reservoir to the net head piezometer section.

Although not specifically required for determining turbine efficiency, an additional piezometer line was installed directly behind the rack structure and was used to determine the head loss due to trashracks alone.

The power output used in computing turbine efficiency was obtained by measuring the electrical output of the units with suitable correction for generator losses. These losses were determined from independent tests on the generators. Power output of the generators was measured by two sets of single-phase wattmeters connected to calibrated standard-station current and potential transformers permanently connected to the generator leads, and these were added to obtain the official generator output. A check on the above readings was obtained by a polyphase wattmeter and a recording wattmeter. The output of the main and pilot exciters, aggregating about 85 kw. at full gate, were included with the main generator output in computing turbine performance. The power factor of the generator load was kept at unity throughout the turbine and combined unit tests.

Preliminary measurements

To determine a pipe factor to be used in connection with the Gibson flow measurement, the final cross sections of the penstock pipes were measured at 10 different points. These were made at 4 different diameters at each of the 10 sections after the dam had been completed, the penstocks cleaned and painted, turbine and generator assembled, and all concrete poured. These 80 measurements averaged 19 feet 11$\frac{3}{16}$ inches and ranged between 19 feet 10$\frac{1}{2}$ inches and 20 feet 1$\frac{1}{8}$ inches.

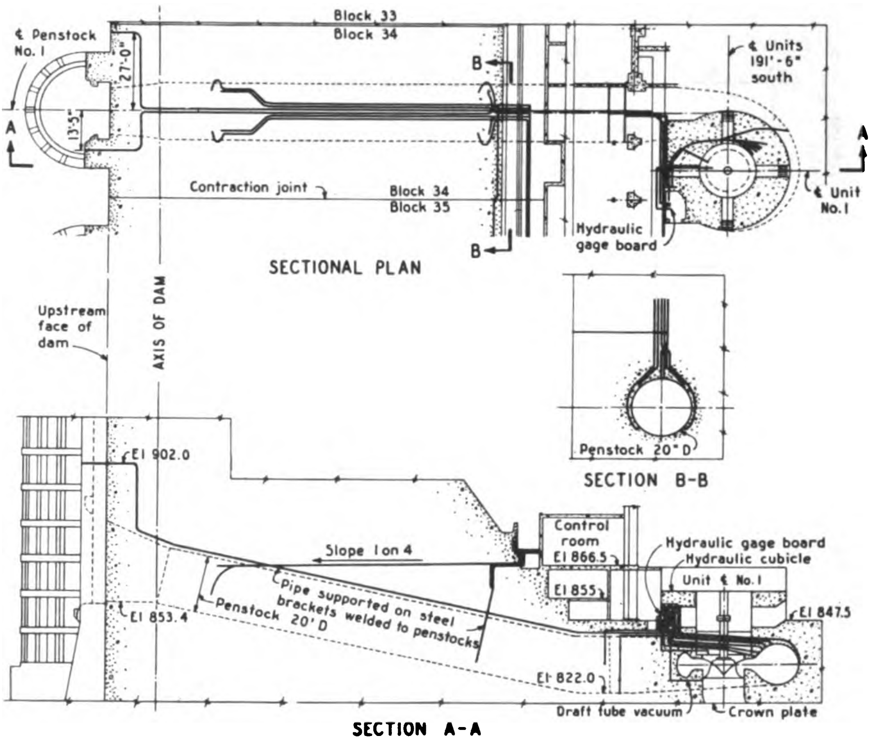


FIGURE 365.—*Piezometer arrangement—Norris.*

Prior to the test, relative densities of mercury and water were computed from Smithsonian tables with due regard to the temperatures. To check the results obtained a manometer was set up in which a 127.80-foot water leg was balanced by a 9.405-foot mercury leg at a temperature of 14.5° C., resulting in a relative density of 13.5885. The mercury used in this test was a portion of that used in the actual tests.

To obtain the total turbine discharge for each test run, it was necessary to add the turbine leakage quantity to the Gibson diagram quantity. The leakage quantity for both turbines was computed from the measured clearances at the bottom, top, and between the turbine gates. The orifice area created by these clearances was computed to be 0.0991 square foot for each of the two units. Experience gained from making leakage tests on other turbines indicates that the coefficient of discharge "C" in the standard orifice formula is approximately unity (1.0) for this type of orifice. With these values and at a head of 170.70 feet on the orifice, the leakage quantity was computed to be 10.4 c.f.s. A value of 10.0 c.f.s. was used for both units, which is approximately 0.22 percent of the turbine discharge (approximately 4,550 c.f.s.) at full gate under a net head of 180 feet.

A governor closing time was chosen to give the most favorable adjustment to the recording apparatus, which was found to be about 15 seconds.

Results of turbine and unit efficiency tests

Results of the turbine and combined unit efficiency tests for 180-feet net head are given in the following tabulation. Figure 366 is a graphical presentation of the same data for unit No. 1. The results were practically the same for the two units. Although the acceptance tests were based on performance at a net head of 180 feet, the curves in figure 366 also present the test data on the basis of performance at a gross head of 180 feet.

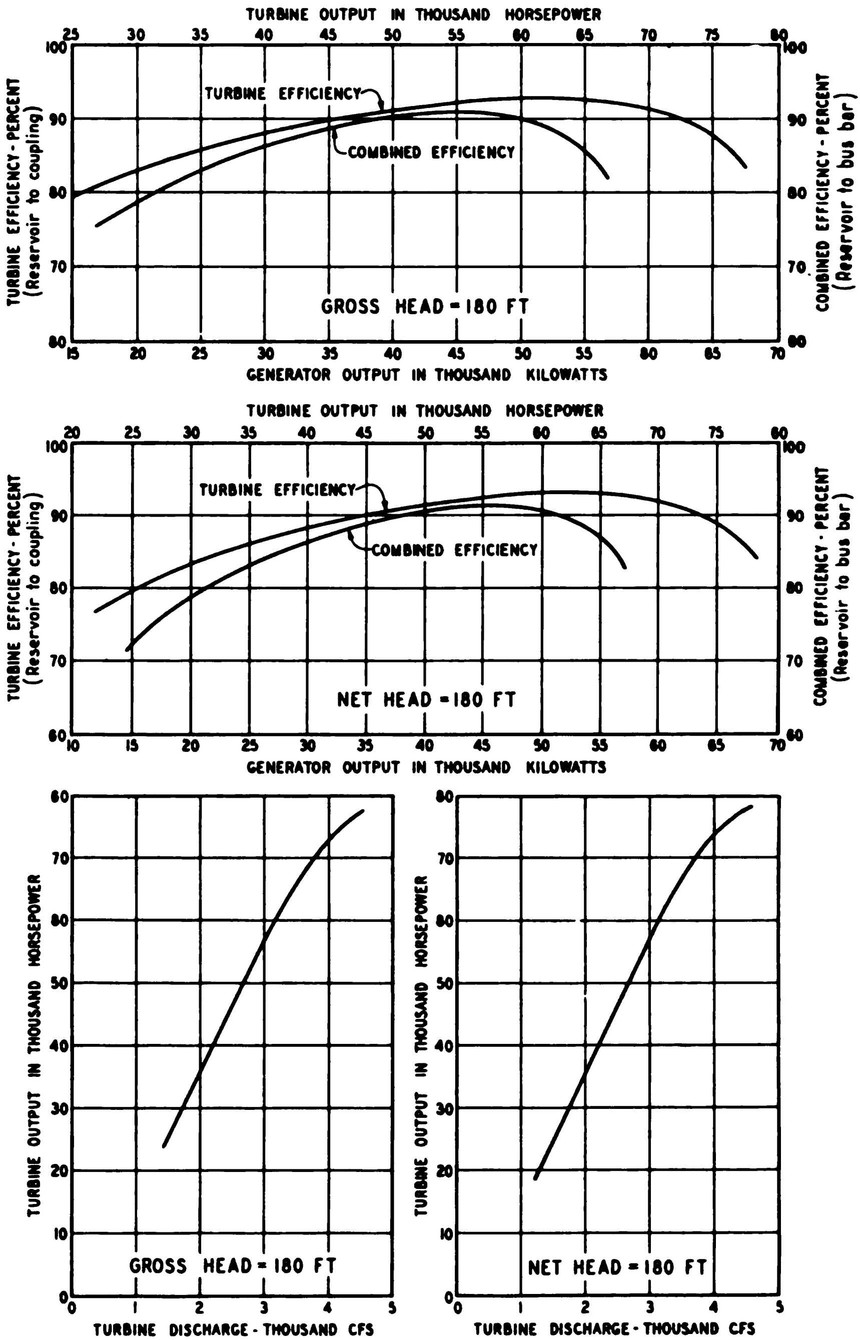


FIGURE 366.—*Graphical results of turbine acceptance tests—Norris.*

Item	Unit of measure	Unit 1	Unit 2	Guarantee
Turbine efficiency at 60,000 hp	Percent	93.1	93.3	91.0
Maximum turbine efficiency	do	93.2	93.3	
Output at maximum efficiency	Horsepower	62,000	62,000	60,000
Generator output at maximum turbine efficiency.	Kilowatt	45,400	45,400	
Discharge at maximum turbine efficiency	Cubic feet per second.	3,250	3,255	
Maximum combined turbine and generator test efficiency.	Percent	91.3	91.5	
Corresponding generator output	Kilowatt	44,000	44,000	
Turbine efficiency at 75-200 hp	Percent	88.9	89.9	86.0
Full gate test capacity:				
Turbine	Horsepower	78,300	78,300	75,200
Turbine efficiency	Percent	84 1	84.0	86.0
Generator	Kilowatt	57,400	57,400	
Turbine discharge	Cubic feet per second.	4,560	4,562	
Guaranteed capacity	Percent	104	104	

The total head loss between the reservoir and turbine amounted to 0.61 foot at full turbine gate opening and 0.33 foot at best gate opening, indicating high overall plant efficiency. The loss at the trashracks amounted to only 0.01 foot.

During the tests made to determine the runaway speed, unit No. 1 attained a speed of 188.8 r.p.m. at 165.3 foot head, while unit No. 2 reached 184.0 r.p.m. at 157.9 foot head, corresponding to a stepped-up value of 211 r.p.m. at the maximum head of 207 feet, or 1.8 percent less than the maximum guaranteed runaway speed of 215 r.p.m. Readings of the mercury manometers attached to the Winter-Kennedy scroll case taps indicated that the discharge is reduced materially under runaway conditions. Full gate discharge was approximately 25 percent less at runaway than at normal operating speed, while the corresponding half-gate discharge was reduced 12 percent.

INDEX TESTS CONDUCTED ON UNITS 1, 2, AND 3 AT WATTS BAR PROJECT

(Data included for unit 1 test only)

Purpose of tests

The purpose of these tests was (1) to check the capacity of the turbines against the manufacturer's guarantees, (2) to obtain data from which the cams could be shaped to give the proper gate-blade relation, (3) to obtain a flowmeter calibration so that the flowmeter dial would read correctly the cubic feet per second of water used by the turbine, and (4) to obtain data so that accurate operating characteristic curves of the turbine could be constructed.

Turbine, governor, and generator data

The turbines installed were manufactured by the Baldwin-Southwark Division of the Baldwin Locomotive Works, Philadelphia, Pa., on contract TV-51328. They are of the Kaplan or automatically adjustable type, rated 42,000 hp. at 52-foot head, 94.7 r.p.m.

The governors were supplied on the turbine contract but were manufactured by the Woodward Governor Co., Rockford, Ill.

The generators were supplied by the Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa., on contract TV-51327. They are rated 33,333 kv.-a., 3 ph., 60 cycles, 13,800 v., 94.7 r.p.m. The machine is equipped with a Westinghouse Kingsbury type thrust bearing and main and pilot exciter.

The combined unit is of the vertical shaft umbrella type with the thrust bearing located below the rotor. The shaft is guided by two guide bearings, one above the thrust bearing directly below the rotor and the second in the turbine head cover above the runner.

Method of conducting test

Arrangements were made with the Department of Operations to vary the load on the machines as the test required. Tests on each machine were made with the runner blades fixed at 0, 5, 10, 15, 20, and 25 degrees tilt. At each blade setting the turbine wicket gates were varied, and readings were taken over the area of maximum efficiency for that particular blade setting.

For obtaining the scroll case differential head on the turbines a water column manometer was connected to the Winter-Kennedy piezometer taps R_1, R_2, R_3, and R_4. The location of these taps is shown on plate 52. At each wicket gate position, readings were made of the manometer. Ten readings of each column were made to insure a correct average. The output of the generator was measured by counting the revolutions of the watt-hour meter, the time being measured accurately by a stop watch. Two sets of watt-hour meter readings were made for each gate position.

The head on the machine was taken from the recording meter located in the main switchboard room.

Table 17 shows the main switchboard readings, recorded during each test for unit 1. This table gives the blade angle, gate position, time, generator output, head, and various other data for possible future reference. Tables 18 and 19 show the turbine and governor readings. These tables give the piezometer readings, gate position, blade angle, cam lift, and various other readings for reference.

Capacity of turbines

At the time the tests were conducted the head was very near 60 feet. To check the turbine capacity against the contract guarantees the data obtained were reduced to a common basis of 60 feet. The computations are given in table 20. The contract guarantee at 60-foot head is 48,000 hp. for each machine.

Unit No. 1 produced 41,300 kw. at 97.25 percent generator efficiency, or 56,900 hp., or 18.52 percent above the contract guarantee.

Unit No. 2 produced 41,670 kw. at 97.25 percent generator efficiency, or 57,400 hp., or 19.58 percent above the contract guarantee.

Unit No. 3 produced 42,180 kw. at 97.25 percent generator efficiency, or 58,100 hp., or 21.04 percent above the contract guarantee.

In computing the above quantities no account has been taken of the losses through the trashrack. These losses probably would amount to ¼ of 1 percent or less.

There are other capacities guaranteed at other heads, and it is felt certain these will be met if not exceeded.

Operating characteristics

For the purpose of constructing the operating characteristic curves the data were computed for a 60-foot head. These curves are shown on plates 53, 54, and 55. In computing these data, a maximum overall efficiency of 90 percent was assumed for power delivered at the switchboard. This takes into account the generator losses, and the turbine and water passage losses.

Kaplan blade operating cam

For the purpose of correctly shaping the cam the data were computed and plotted as each reading was taken. After all three units were tested, the theoretical cam lift was laid out on the face of the cam and the excess metal removed. The cams for all three governors were computed to be within 0.040 inch of each other. This in terms of efficiency is less than one-fourth of 1 percent; therefore, all cams were shaped alike. The maximum amount of metal removed from any one cam was 0.140 inch. The readings made after the cams were reshaped are shown on tables 21 and 22. Figure 367 shows curves for shaft deflections and Kaplan blade and wicket gate oil pressures for various gate openings.

Additional tests should be conducted to determine the accuracy of these cams at lower head positions.

Flow meter calibration

The flow meters are built for a total deflection of 50 inches of water. For the purpose of obtaining a constant for these flow meters the piezometer taps R_4-R_2 were used. These taps were found to be more reliable than either R_4-R_1, or R_4-R_3, and the deflection in inches was less than 50. The coefficient for the discharge was found to be 5493.7 for unit No. 1, 5472.9 for unit No. 2, and 5393.0 for unit No. 3. This constant was obtained by dividing the cubic feet per second at 90 percent efficiency by $\sqrt{R_4-R_2}$ at this point. These coefficients were used in laying out the temporary dials for the flow meters.

Personnel

These tests were conducted under the supervision of Mr. W. K. Beattie of the Baldwin-Southwark Division of the Baldwin Locomotive Works and Mr. C. L. Norris of the TVA Division of Design, with assistance from members of the Division of Power Operations under Mr. Van S. Pickel and the Engineering and Construction Departments under Messrs. F. C. Schlemmer, F. E. Bell, and Ray Thorne. This report was prepared by Messrs. C. L. Norris and J. R. Parrish.

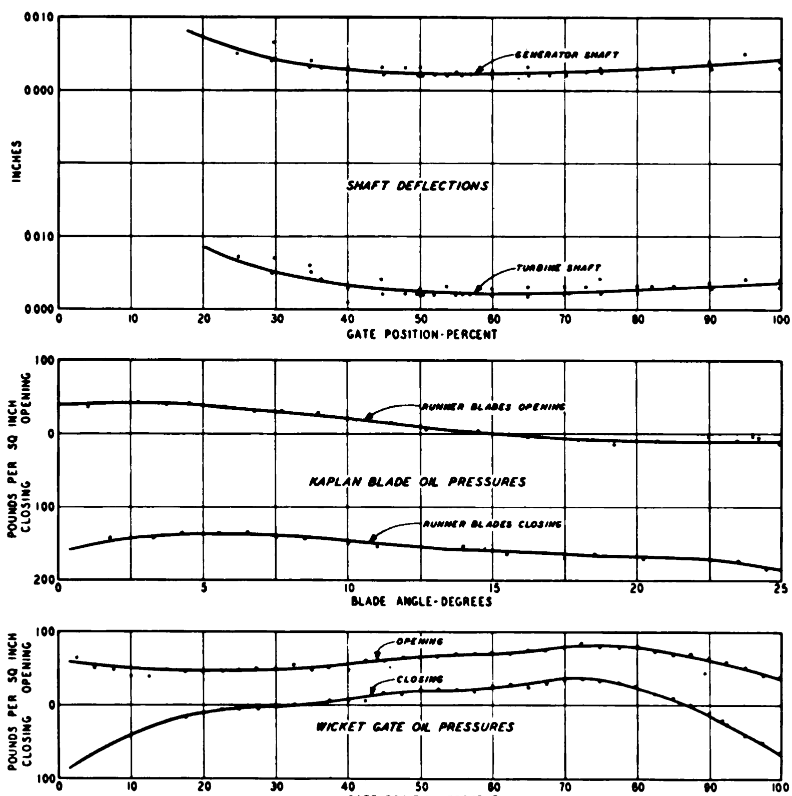
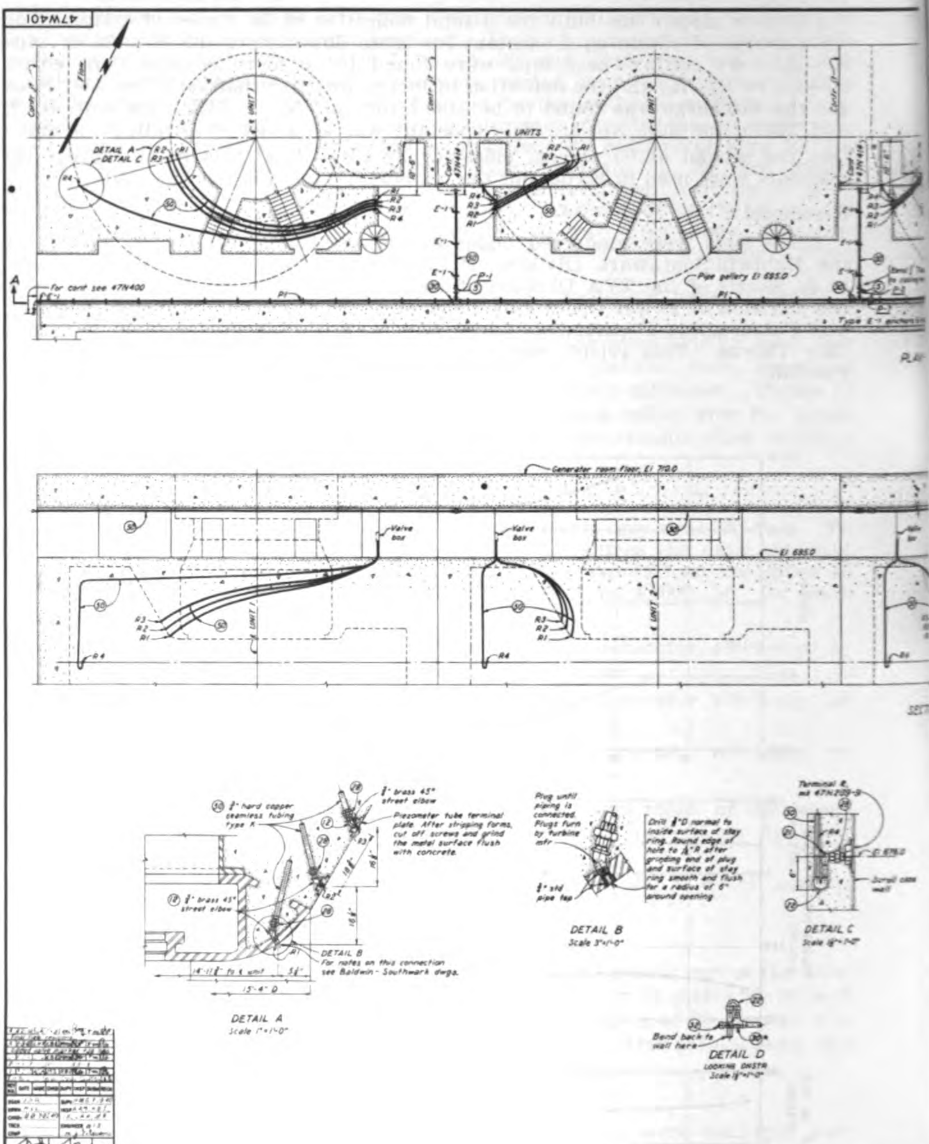
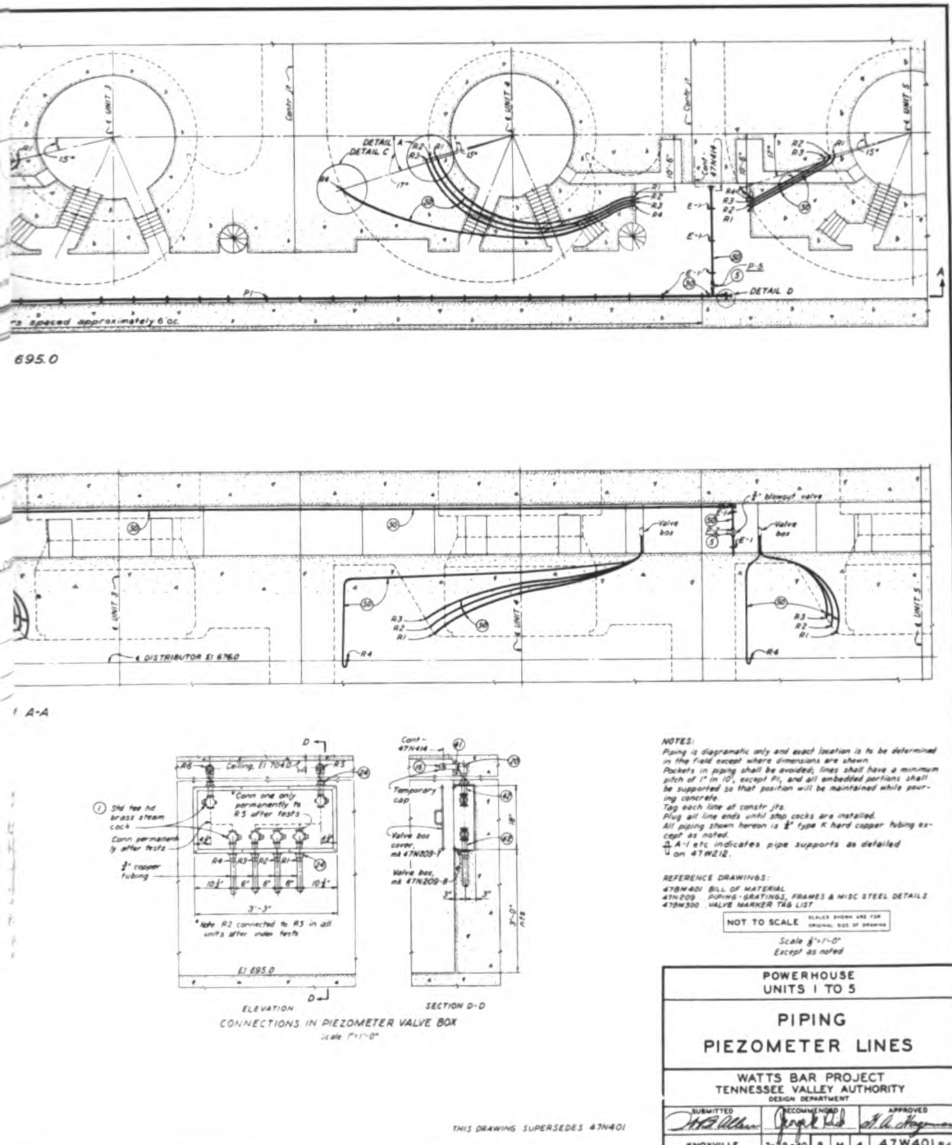
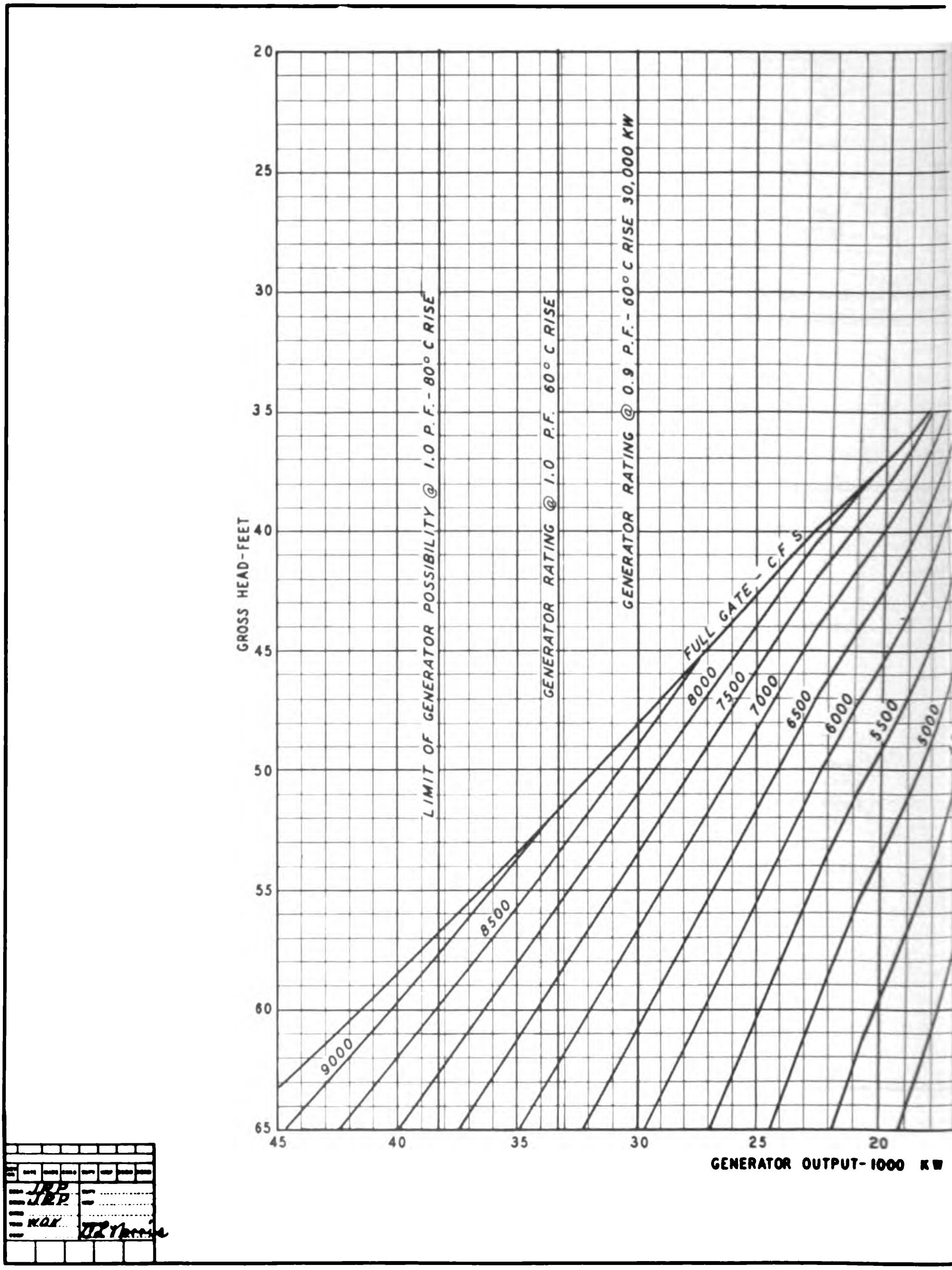


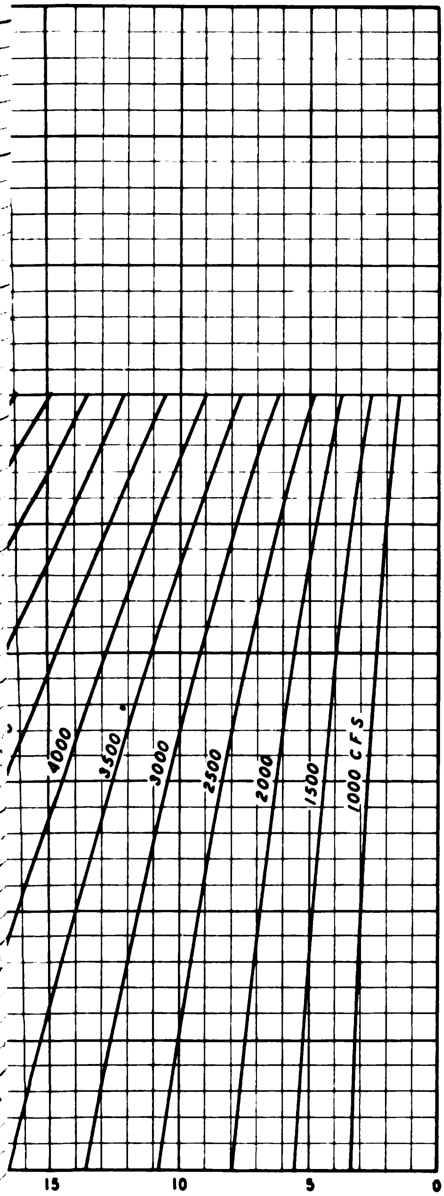
FIGURE 367.—*Shaft deflections, Kaplan blade oil pressures, and wicket gate oil pressures—Watts Bar unit 1 tests.*


47W401
DETAIL A
DETAIL C
For cont see 47N400
Pipe gallery El 695.0
PLAN
Generator room floor, El 710.0
Valve box
El 695.0
hard copper seamless tubing type K
brass 45° street elbow
Piezometer tube terminal plate. After stripping forms, cut off screws and grind the metal surface flush with concrete.
DETAIL B
For notes on this connection see Baldwin-Southwark dwg.
DETAIL A
Scale 1"=1'-0"
Plug until piping is connected. Plugs furn by turbine mfr
std pipe tap
around opening
DETAIL B
Scale 3"=1'-0"
Scroll case wall
DETAIL C
Bend back to wall here
DETAIL D
LOOKING DNSTR



DETAIL A
DETAIL C
℄ UNIT 3
℄ UNIT 4
℄ UNIT 5
Centr jt
P1
DETAIL D
...rs spaced approximately 6' o.c.
695.0
½" blowout valve
Valve box
℄ DISTRIBUTOR El 676.0
A-A
NOTES:
Piping is diagramatic only and exact location is to be determined in the field except where dimensions are shown.
Pockets in piping shall be avoided; lines shall have a minimum pitch of 1" in 10', except P1, and all embedded portions shall be supported so that position will be maintained while pouring concrete.
Tag each line at constr jts.
Plug all line ends until stop cocks are installed.
All piping shown hereon is ½" type K hard copper tubing except as noted.
A-1 etc indicates pipe supports as detailed on 47W212.
REFERENCE DRAWINGS:
47BM401 BILL OF MATERIAL
47N209 PIPING-GRATINGS, FRAMES & MISC STEEL DETAILS
47BM300 VALVE MARKER TAG LIST
NOT TO SCALE
Scale ⅛"=1'-0"
Except as noted
Std tee hd brass steam cock
Conn permanently after tests
½" copper tubing
*Conn one only permanently to R5 after tests
*Note R2 connected to R5 in all units after index tests
Ceiling, El 704.0
El 695.0
Temporary cap
Valve box cover, mk 47N209-7
Valve box, mk 47N209-8
ELEVATION
SECTION D-D
CONNECTIONS IN PIEZOMETER VALVE BOX
Scale 1"=1'-0"
THIS DRAWING SUPERSEDES 47N401
POWERHOUSE
UNITS 1 TO 5
PIPING
PIEZOMETER LINES
WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
47W401 R4


GROSS HEAD-FEET
20
25
30
35
40
45
50
55
60
65
45
40
35
30
25
20
GENERATOR OUTPUT-1000 KW
LIMIT OF GENERATOR POSSIBILITY @ 1.0 P.F.-80° C RISE
GENERATOR RATING @ 1.0 P.F. 60° C RISE
GENERATOR RATING @ 0.9 P.F.-60° C RISE 30,000 KW
FULL GATE C.F.S.
9000
8500
8000
7500
7000
6500
6000
5500
5000



NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 11-20-42. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. T.V. 51328 rated 42,000 hp, 52 ft head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg. Co. T.V. 51327 rated, 33,333 KVA, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

POWERHOUSE

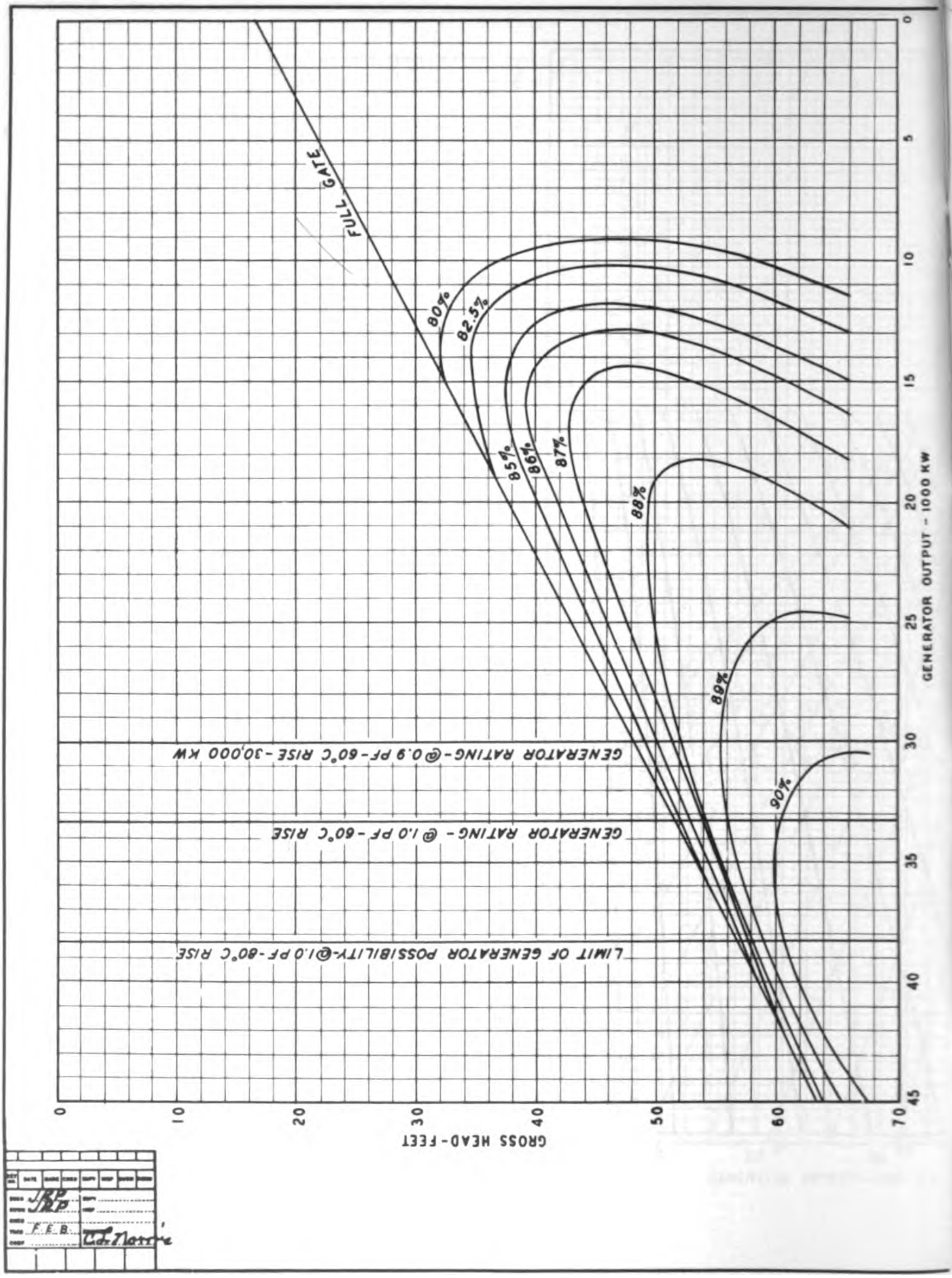
DISCHARGE CURVES
BASED ON INDEX TESTS

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED RECOMMENDED APPROVED

KNOXVILLE 4-10-43 9 M 4 47B901 RO

PLATE 53


FULL GATE
80%
82.5%
85%
86%
87%
88%
89%
90%
GENERATOR RATING-@0.9 PF-60°C RISE-30,000 KW
GENERATOR RATING- @1.0 PF-60°C RISE
LIMIT OF GENERATOR POSSIBILITY-@1.0 PF-80°C RISE
GROSS HEAD-FEET
GENERATOR OUTPUT - 1000 KW
0
10
20
30
40
50
60
70
5
15
25
35
45

NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin-Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 11-20-42. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV. 51328 rated 42000 hp, 52 ft head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg Co. TV. 51327 rated, 33,333 KVA, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60° C rise.

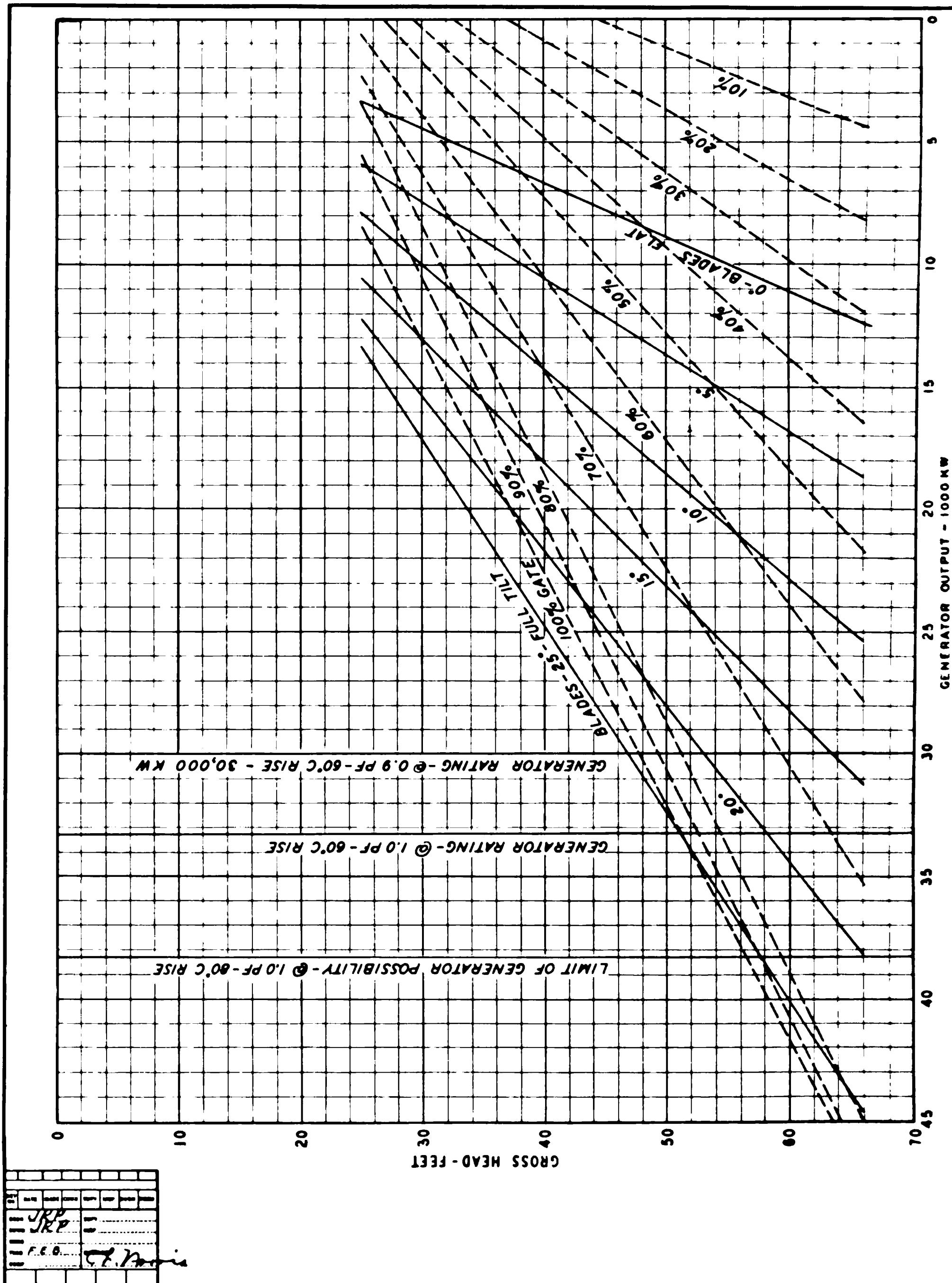
POWERHOUSE

OPERATING CHARACTERISTICS
OF 33,333 KVA
GENERATING UNIT

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED RECOMMENDED APPROVED

KNOXVILLE 4-1?-43 9 M 4 47B900 R0


GENERATOR OUTPUT - 1000 KW
GROSS HEAD - FEET
GENERATOR RATING - @ 0.9 PF - 60°C RISE - 30,000 KW
GENERATOR RATING - @ 1.0 PF - 60°C RISE
LIMIT OF GENERATOR POSSIBILITY - @ 1.0 PF - 80°C RISE
0° - BLADES - FLAT
25° - BLADES - 25° - FULL TILT
100% GATE
10%
20%
30%
40%
50%
60%
70%
80%
90%
5°
10°
15°
20°

NOTES:

These performance curves are based on performance of 11" model runner tested in Baldwin - Southwark Laboratory. Test No. 645 modified in accordance with index test conducted at the plant on 11-20-42. Additional tests should be made at lower heads and these curves revised accordingly.

Turbines furnished by Baldwin-Southwark Corp. TV. 51328 rated 42000 hp, 52 ft head, 94.7 rpm, 5 blade adjustable Kaplan runner.

Generators furnished by Westinghouse Electric Mfg Co. TV. 51327 rated, 33,333 KVA, 3 phase, 60 cycles, 13,800 volts, 0.9 pf, 94.7 rpm, 60°c rise.

POWERHOUSE

WICKET GATE
RUNNER BLADE RELATIONS

WATTS BAR PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 4-10-43 | 9 | M | 4 | 47B902 R0

PLATE 55

TABLE 17.—*Switchboard readings—unit 1*

Time Nov. 19, 1942	Kilovolts	Gate position—percent	Blade angle—degrees	A.c. amps. average	Megawatts indicated	Mvar	Power factor	Main exciter		Megawatts from load recorder	Revolutions	Time—seconds	Calculated [1] megawatts	Headwater elevation	Tailwater elevation	Net head—feet
								Volts	Amps.							
A.M.																
8:06	13.8	0	0	25	−1	0	1.0	110	390	−0.5	1	200	−0.576	740.11	679.57	60.54
8:13	13.8	30	0	400	9.9	0	1.0	110	390	9.5	5 5	61.0 61.1	9.443 9.427	740.08	679.66	60.42
8:28	13.8	35	0	450	11.3	0	1.0	111	400	11.0	8 8	83.6 83.6	11.024 11.024	740.11	679.61	60.50
8:38	13.8	40	2.5	550	13.2	0	1.0	111	400	13.0	8 8	70.1 70.0	13.147 13.166	740.07	679.57	60.50
8:44	13.8	50	8	800	19.5	0	1.0	119	430	19.5	10 10	60.0 59.9	19.200 19.232	740.09	679.58	60.51
8:50	13.8	60	14	1050	26.0	0	1.0	125	470	25.5	15 15	68.4 68.4	25.263 25.263	740.05	679.66	60.39
8:56	13.8	70	19	1320	33.0	0	1.0	140	520	32.0	18 18	65.1 65.2	31.853 31.804	740.05	679.80	60.25
9:03	13.8	80	23	1550	38.5	0	1.0	150	560	37.0	20 20	62.3 62.5	36.983 36.864	740.08	679.87	60.21
9:50	13.7	90	23.5	1650	40.5	0	1.0	160	580	40.0	20 20	58.2 58.2	39.588 39.588	740.09	679.88	60.21
10:04	13.6	100	23.5	1700	41.0	0	1.0	160	590	40.5	25 25	72.1 71.8	39.945 40.112	740.06	679.89	60.17
11:16	13.7	75	25	1525	38.0	0	1.0	154	560	37	20 20	63.6 63.1	36.228 36.513	740.10	679.56	60.54
11:22	13.7	80	25	1610	40.0	0	1.0	159	580	39	20 20	59.9 59.8	38.464 38.528	740.09	679.64	60.45
11:27	13.7	82	25	1650	40.0	0	1.0	159	580	39.5	25 25	73.5 73.5	39.184 39.184	740.14	679.73	60.41
11:32	13.7	85	25	1675	41.0	0	1.0	160	590	40.3	25 25	72.2 72.4	39.880 39.779	740.12	679.73	60.39
11:38	13.7	90	25	1700	41.5	0	1.0	162	600	41	25 25	71.1 71.1	40.507 40.507	740.05	679.75	60.35
11:43	13.7	95	25	1720	42.0	0	1.0	162	600	41.5	25 25	70.3 70.3	40.967 40.967	740.05	679.77	60.32
11:48	13.7	100	25	1725	42	0	1.0	167	605	41.8	25 25	69.8 69.6	41.261 41.370	740.07	679.77	60.30
P.M.																
12:02	13.8	65	20	1225	30.5	0	1.0	140	410	30	18 18	69.4 69.2	29.879 29.965	740.05	679.51	60.54
12:07	13.8	70	20	1325	33.5	0	1.0	145	430	32.5	18 18	64.2 64.3	32.299 32.241	740.06	679.61	60.45
12:14	13.8	73	20	1360	34	0	1.0	150	440	33.2	18 18	62.8 62.9	33.019 32.967	740.06	679.62	60.44

12:18	13.8	75	20	1375	35	0	1.0	150	440	33.8	20	69.0	33.391	740.08	679.59	60.49
											20	68.7	33.537			
12:23	13.8	80	20	1425	35.5	0	1.0	150	440	34.5	20	66.9	34.439	740.09	679.60	60.49
											20	67.0	34.388			
12:28	13.8	85.5	20	1460	36.5	0	1.0	150	450	35.5	20	65.5	35.175	740.09	679.55	60.54
											20	65.4	35.229			
12:41	13.8	60.5	15	1075	27	0	1.0	134	485	36.4	15	63.0	26.182	740.08	679.39	60.69
											15	66.1	23.142			
12:49	13.8	65	15	1150	29	0	1.0	134	490	28	15	62.0	27.871	740.05	679.43	60.62
											15	62.0	27.871			
12:56	13.8	70	15	1150	29.5	0	1.0	135	490	28.5	15	60.6	28.515	740.04	679.46	60.58
											15	60.6	28.515			
1:02	13.8	70.5	15	1200	29.5	0	1.0	136	500	29	15	60.2	28.704	740.05	679.47	60.58
											15	60.1	28.752			
1:07	13.8	75	15	1220	30	0	1.0	136	500	30	18	70.4	29.455	740.06	679.48	60.58
											18	70.2	29.538			
1:13	13.8	80	15	1250	31	0	1.0	137	500	30.2	18	69.3	29.922	740.09	679.48	60.61
											18	69.2	30.008			
1:25	13.8	45.5	10	1775	19.2	0	1.0	118	420	18.8	10	61.7	18.671	740.10	679.42	60.68
											10	62.0	18.581			
1:29	13.8	50	10	850	21	0	1.0	121	445	21	12	66.6	20.757	740.10	679.35	60.75
											12	66.6	20.757			
1:36	13.8	53	10	875	21.6	0	1.0	121	445	21.5	12	65.4	21.138	740.10	679.34	60.76
											12	65.5	21.105			
1:42	13.8	55	10	900	22.5	0	1.0	121	445	22	12	63.1	21.908	740.08	679.40	60.68
											12	63.2	21.873			
1:48	13.8	60.5	10	950	23.5	0	1.0	121	440	23	12	60.4	22.887	740.07	679.44	60.63
											12	60.4	22.887			
1:53	13.8	65.5	10	975	24.0	0	1.0	121	450	23.6	15	73.6	23.478	740.06	679.45	60.61
											15	73.8	23.414			
1:59	13.8	70	10	1000	24.5	0	1.0	122	460	24	12	57.4	24.081	740.05	679.45	60.60
											12	57.6	24.000			
2:08	13.8	55	10	900	22.0	0	1.0	122	450	22	12	64.4	21.466	740.08	679.48	60.60
											12	64.4	21.466			
2:13	13.8	57	10	925	23.0	0	1.0	121	450	22.5	12	61.4	22.515	740.08	679.48	60.60
											12	61.4	22.515			
2:18	13.8	55	10	900	23.0	0	1.0	123	470	22.5	12	63.1	21.903	740.09	679.47	60.62
											12	63.5	21.770			
2:35	13.8	35.5	5	550	13.0	0	1.0	110	400	13.2	8	70.8	13.017	740.09	679.38	60.71
											8	70.7	13.035			
2:40	13.8	40	5	625	15	0	1.0	110	400	15	8	61.9	14.889	740.08	679.32	60.76
											8	61.7	14.937			
2:46	13.8	45	5	675	16.4	0	1.0	110	400	16	10	71.4	16.134	740.06	679.32	60.74
											10	71.2	16.180			
2:53	13.8	48.5	5	700	17	0	1.0	115	420	16.8	10	68.8	16.744	740.06	679.36	60.70
											10	69.0	16.696			
2:58	13.8	50	5	700	17	0	1.0	115	420	17	10	68.0	16.941	740.06	679.37	60.69
											10	68.2	16.891			
3:04	13.8	55	5	725	17.6	0	1.0	115	420	17.8	10	65.9	17.481	740.05	679.41	60.64
											10	65.8	17.506			
3:10	13.8	60.5	5	750	18.0	0	1.0	115	420	18.0	10	64.4	17.888	740.07	679.40	60.67
											10	64.2	17.944			

See footnote at end of table

TABLE 17.—*Switchboard readings—unit 1*—Continued

Time Nov. 19, 1942	Kilo-volts	Gate position—percent	Blade angle—degrees	A.c. amps. average	Megawatts indicated	Mvar	Power factor	Main exciter		Megawatts from load recorder	Revolutions	Time—seconds	Calculated [1] megawatts	Head-water elevation	Tailwater elevation	Net head—feet
								Volts	Amps.							
P.M.																
3:20	13.8	25	0.5	300	8	0	1.0	105	390	8	5	72.5	7.945	740.09	679.30	60.79
											5	72.1	7.989			
3:27	13.8	30	0.5	400	10	0	1.0	105	390	10	5	59.4	9.697	740.10	679.36	60.74
											5	59.5	9.681			
3:32	13.8	35	0.5	450	11.5	0	1.0	105	390	11	8	82.9	11.117	740.10	679.32	60.78
											8	82.8	11.130			
3:44	13.8	40	0.5	500	12	0	1.0	108	400	11.8	8	77.6	11.876	740.07	679.32	60.75
											8	77.8	11.846			
3:50	13.8	45	0.5	500	12.5	0	1.0	108	400	12.5	8	74.4	12.387	740.07	679.32	60.75
											8	74.4	12.387			
3:58	13.8	50	0.5	500	13.0	0	1.0	108	400	12.8	8	72.6	12.694	740.06	679.32	60.74
											8	72.2	12.765			

[1] Calculated megawatts $=115.2\times\frac{\text{revolutions}}{\text{seconds}}$.

TABLE 18.—*Turbine readings—unit 1*

Time Nov. 19, 1942	Height cam follower—in.	Piston stroke—in.	Gate position, percent	Blade angle—degrees	Feet of water			Head—ft.	Head cover pressure—ft.	Shaft throw-out—in.	
					R_4-R_1	R_4-R_2	R_4-R_3			Generator	Turbine
A. M.											
8:13	6.796	8.000	30	0	0.16	0.178	0.14	60.42	18.	0.004	0.005
8:29	6.868	9.719	37	0	.21	.226	.18	60.50	22	.003	.004
8:38	6.971	10.547	40	2.5	.27	.299	.24	60.50	18	.001	.001
8:43	7.258	12.985	50	8	.54	.593	.48	60.51	16.5	.002	.002
8:51	7.536	15.578	60	14	.89	1.017	.82	60.39	16	.002	.002
8:56	7.791	18.125	70	19	1.39	1.58	1.29	60.25	17	.002	.002
9:04	7,998	20,578	80	23	1.90	2.306	1.78	60.21	19	.002	.003
9:50	8.038	23.172	90	23.5	2.27	2.596	2.11	60.21	26.5	.003	.003
10:04	8.038	25.765	100	23.5	2.58	2.84	2.30	60.17	32.0	.003	.003
11:17	8.023	19.281	75	25	1.91	2.258	1.81	60.54	8	.003	.004
11:23	8.023	20.593	80	25	2.11	2.462	1.98	60.45	12	.003	.003
11:28	8.023	21.141	82	25	2.16	2.537	2.04	60.41	15	.003	.003
11:32	8.023	21.922	85	25	2.29	2.64	2.11	60.39	18	.003	.003
11:38	8.023	23.172	90	25	2.40	2.784	2.23	60.35	22	.004	.0035
11:43	8.023	24.360	95	25	2.57	2.921	2.36	60.32	26	.005	.004
11:48	8.023	25.765	100	25	2.74	3.054	2.48	60.30	29	.004	.004
P. M.											
12:01	7.755	16.859	65	20	1.30	1.47	1.19	60.54	5	.003	.003
12:07	7.755	18.188	70	20	1.43	1.63	1.32	60.45	12	.002	.003
12:14	7.755	18.859	73	20	1.50	1.703	1.37	60.44	15	.0025	.003
12:18	7.755	19.406	75	20	1.53	1.756	1.42	60.49	18	.003	.002
12:24	7.755	20.651	80	20	1.61	1.874	1.41	60.49	--------	.003	.003
12:29	7.755	22.000	85	20	1.71	1.978	1.59	60.54	--------	.0025	.003
12:41	7.520	15.640	60	15	.97	1.09	.88	60.69	--------	.002	.0025
12:48	7.520	16.875	65	15	1.05	1.204	.97	60.62	--------	.002	.0015
12:56	7.520	17.672	68	15	1.09	1.259	1.02	60.58	--------	.002	.002

TABLE 19.—*Turbine pressures—unit 1*

Gate position	Right-hand cylinder pressure—p.s.i.	Left-hand cylinder pressure—p.s.i.	Difference—p.s.i.	Blade angle—degrees	Pressure		Difference p.s.i.
					To open, p.s.i.	To close, p.s.i.	
2.5	185	120	65	0	50	135	85
5	175	125	50	0	45	140	95
7.5	175	130	45	0	50	145	95
10	170	130	40	0	50	140	90
12.5	170	130	40	0	50	137	87
15	175	130	45	0	50	135	85
17.5	175	130	45	0	50	138	88
20	175	130	45	0	47	140	93
22.5	175	130	45	0	45	145	100
25	175	130	45	0	40	150	110
27.5	175	125	50	0	45	165	120
30	175	125	50	0	48	165	117
32.5	180	125	55	⅛	50	160	110
35	175	125	50	¼	40	165	125
37.5	175	125	50	¼	--------	175	--------
40	175	125	50	⅓	140	200	60
42.5	180	120	60	1	145	110	35
45	180	120	60	2¾	145	105	40
47.5	180	115	65	3¾	145	105	40
50	180	115	65	4½	145	105	40
52.5	180	115	65	5¾	140	105	35
55	185	115	60	6¾	140	110	30
57.5	185	115	60	7¾	140	110	30
60	185	115	60	9	137	110	27
62.5	185	115	60	10	135	115	20

TABLE 19.—*Turbine pressures—unit 1*—Continued

Gate position	Right-hand cylinder pressure—p.s.i.	Left-hand cylinder pressure—p.s.i.	Difference—p.s.i.	Blade angle—degrees	Pressure		Difference p.s.i.
					To open, p.s.i.	To close, p.s.i.	
65	190	115	75	11½	132	120	12
67.5	190	115	75	12¾	130	125	5
70	195	115	80	14½	130	125	5
72.5	200	115	85	16¼	125	130	5
75	200	120	80	18	125	135	10
77.5	200	120	80	19¼	125	140	15
80	200	120	80	20¾	130	140	10
82.5	195	120	75	22½	135	140	5
85	195	125	70	23½	135	145	10
87.5	200	130	70	24¼	140	145	5
90	200	135	65	25	140	155	15
92.5	195	135	60	25	137	165	28
95	190	140	50	25	130	170	40
97.5	185	145	40	25	120	175	55
100	190	150	40	25	100	175	75
100	130	195	65	25	60	165	100
97.5	140	190	50	25	65	110	45
95	145	185	40	25	70	100	30
92.5	150	175	25	25	75	95	20
90	160	170	10	25	75	90	15
87.5	165	165	0	25	80	85	5
85	170	160	10	25	80	85	5
82.5	175	160	15	25		85	
80	180	155	25	25	45	230	185
77.5	180	150	30	24½	47	230	183
75	185	150	35	23½	50	225	175
72.5	185	150	35	21¾	50	220	170
70	185	150	35	20¼	50	220	170
67.5	175	145	30	18½	50	215	165
65	175	150	25	17½	50	220	170
62.5	175	145	20	15½	50	215	165
60	175	150	25	14	55	210	155
57.5	175	155	20	12½	55	210	155
55	170	150	20	11	55	210	155
52.5	170	150	20	10	60	210	150
50	170	150	20	8½	60	205	145
47.5	160	145	25	7½	62	205	143
45	165	150	15	6½	62	200	138
42.5	160	155	5	5½	62	200	138
40	160	155	5	4¼	62	200	138
37.5	160	155	5	3¼	57	200	143
35	150	150	0	1¾	52	205	143
32.5	155	155	0	¾	52	210	158
30	150	150	0	¼	0	210	210
27.5	150	155	5	⅛	0	255	256
25	150	155	5	0	0	255	255
22.5	150	155	5	0	0	255	255
20	150	160	10	0	0	255	255
17.5	145	160	15	0	0	255	255
				0	0	255	256
				0	0	255	255
				0	0	255	255
				0	0	255	255
				0	0	250	250
				0	0	250	250
				0	10	245	235
				0	50	235	185

TABLE 20.—*Computations—unit 1*

Blade angle—degrees	Gate position—percent	Gross head—ft.	R_4-R_2 Feet of water	Kilowatts	Corrected to 60-foot head: Kilowatts	$\sqrt{R_4-R_2}$	$\frac{Kw}{Hd\times\sqrt{R_4-R_2}}$
25	75	60.54	2.258	36,369	35,900	1.503	399.5
25	80	60.45	2.462	38,496	38,060	1.569	408.7
25	82	60.41	2.537	39,184	38,800	1.593	407.1
25	85	60.39	2.64	39,864	39,475	1.625	406.1
25	90	60.35	2.784	40,507	40,150	1.669	402.3
25	95	60.32	2.921	40,967	40,630	1.71	397.1
25	100	60.30	3.054	41,320	41,015	1.747	392
20	65	60.54	1.47	29,907	29,520	1.212	407.7
20	70	60.45	1.63	32,270	31,980	1.288	414
20	73	60.44	1.703	32,993	32,640	1.305	418
20	75	60.49	1.756	33,464	33,060	1.325	417.3
20	80	60.49	1.874	34,414	34,000	1.369	415.6
20	85	60.54	1.978	35,202	34,750	1.406	413.5
15	60	60.69	1.09	26,162	25,720	1.044	413
15	65	60.62	1.204	27,871	27,450	1.097	418.8
15	68	60.58	1.259	28,515	28,000	1.122	419.5
15	70	60.58	1.283	28,728	28,300	1.133	418.8
15	75	60.58	1.362	29,497	29,060	1.167	417
15	80	60.61	1.44	29,965	29,520	1.2	411.8
10	45	60.68	.586	18,626	18,310	.766	400.5
10	50	60.75	.683	20,757	20,300	.826	413.5
10	52.2	60.76	.722	21,127	20,725	.849	409.5
10	55.2	60.68	.768	21,891	21,520	.876	411.7
10	53.8	60.60	.743	21,466	21,150	.862	410.9
10	55.6	60.62	.77	21,898	21,570	.877	411.8
10	57.2	60.60	.791	22,515	22,180	.889	417.9
10	60.1	60.63	.826	22,839	22,525	.909	414.7
10	65	60.61	.882	23,451	23,100	.939	412.1
10	70.1	60.60	.94	24,042	23,685	.969	409.4
5	34.9	60.71	.322	13,026	12,795	.568	377.7
5	40.1	60.76	.382	14,913	14,625	.618	397.1
5	45.1	60.74	.426	16,157	15,850	.653	407.4
5	48.2	60.70	.453	16,720	16,425	.673	409.3
5	50.0	60.69	.463	16,916	16,630	.68	409.9
5	55.3	60.64	.507	17,493	17,220	.712	405.2
5	60.1	60.67	.537	17,916	17,615	.733	402.9
½	24.9	60.79	.152	7,967	7,800	.39	336
½	29.9	60.74	.188	9,689	9,500	.434	367.5
½	35.1	60.78	.229	11,123	10,900	.478	382.8
½	39.8	60.75	.250	11,861	11,635	.50	390.5
½	45.1	60.75	.280	12,387	12,150	.529	385.4
½	49.8	60.74	.297	12,785	12,540	.545	386.2

Data from smooth curve—60-foot head

Kilowatts	$\frac{Kw}{Hd\times\sqrt{R_4-R_2}}$	Efficiency	Cubic feet per second	Gate position—percent	Blade angle—degrees
9,300	364	78.2	2,335	30	0.5
10,800	382.8	82.3	2,580	35	0.5
13,060	397.9	85.5	3,000	40	2.4
15,320	406.2	87.3	3,450	45	4.3
18,210	411.8	88.5	4,060	50	6.9
21,600	415.2	89.2	4,760	55	10
24,230	417.3	89.7	5,315	60	12.1
26,870	418.1	89.8	5,880	65	14.2
29,700	418.8	89.9	6,490	70	16.7
30,700	418.9	90	6,710	71.7	17.6
32,670	418.6	89.9	7,145	75	19.5
36,020	416	89.4	7,925	80	22.2
39,490	406	87.2	8,900	85	25
40,000	402.9	86.6	9,090	90	25
40,530	398.4	85.6	9,310	95	25
41,300	392	84.2	9,640	100	25

$$\frac{\text{Q at 90 percent Efficiency}}{\sqrt{R_4-R_2}} = \text{Discharge coefficient} = 5493.7$$ (for calibration of turbine discharge flow meter).

TABLE 21.—*Check readings after reshaping cam—unit 1*

Time Nov. 20, 1942	Height cam follower—ins.	Piston stroke—ins.	Gate position, percent	Blade angle—degrees	Feet of water			Head—ft.
					R_4-R_1	R_4-R_2	R_4-R_3	
A. M.								
8:33	6.792	8.109	30	0.25	0.240	0.190	0.149	60.87
8:43	6.801	9.828	37	.50	.211	.229	.180	60.74
8:49	6.892	10.609	40	2.5	.277	.297	.235	60.76
8:56	7.104	13.094	50	7	.488	.549	.440	60.70
9:05	7.347	15.578	60	11.5	.795	.902	.725	60.68
9:16	7.640	18.016	70	17.0	1.255	1.440	1.157	60.56
9:24	7.950	20.719	80	23.5	1.944	2.282	1.826	60.49
9:29	8.036	23.156	90	25.0	2.420	2.795	2.249	60.40
9:35	8.036	25.765	100	25.0	2.724	3.073	2.483	60.38

TABLE 22.—*Check readings—unit 1*

Time Nov. 20, 1942	Kilovolts	Gate position—percent	Blade angle—degrees	A.C. amps. average	Megawatts indicated	Mvar	Power factor	Main exciter		Megawatts from load recorder	Revolutions	Time—seconds	Calculated [1] megawatts	Headwater elevation	Tailwater elevation	Net head—ft.
								Volts	Amps							
A. M.																
8:33	13.9	30	¼	400	9.9	0	1.0	110	395	9.4	5	59.7	9.648	740.17	679.30	60.87
											5	60.1	9.584			
8:43	13.9	37	½	450	11.1	0	1.0	110	395	10.8	8	82.7	11.144	740.16	679.42	60.74
											8	82.6	11.157			
8:49	13.8	40	2½	525	13.4	0	1.0	110	400	12.9	8	69.3	13.299	740.17	679.41	60.76
											8	69.8	13.203			
8:56	13.9	50	7	750	18.8	0	1.0	118	430	18.3	10	62.7	18.373	740.17	679.47	60.70
											10	62.6	18.403			
9:05	14.0	60	11½	970	24.5	0	1.0	128	472	23.9	12	57.5	24.042	740.14	679.46	60.68
											12	57.3	24.126			
9:10	13.9	70	17	1,240	31.4	0	1.0	139	515	30.7	18	68.5	30.272	740.16	679.60	60.56
											18	68.4	30.316			
9:23	13.8	80	23½	1,550	39.2	0	1.0	150	555	37.5	20	61.3	37.586	740.14	679.65	60.49
											20	61.5	37.463			
9:28	13.8	90	25	1,670	42.1	0	1.0	160	598	40.8	25	71.2	40.449	740.12	679.72	60.40
											25	71.3	40.393			
9:35	13.8	100	25	1,720	43.2	0	1.0	161	600	41.5	25	69.8	41.261	740.15	679.77	60.38
											25	69.7	41.320			

[1] Calculated megawatts $= \frac{115.2 \times \text{revolutions}}{\text{seconds}}$

INDEX TEST CONDUCTED ON UNIT NO. 3—DOUGLAS PROJECT, FRANCIS UNIT

(First installation)

Purpose of test

. The purpose of this index test was .(1) to check the capacity of the turbine against the manufacturers' guarantees, (2) to obtain a flowmeter calibration so that the flowmeter dial would read correctly the cubic feet per second of water used by the turbines, and (3) to obtain data, so that accurate operating characteristic curves of the turbine could be constructed.

Turbine, governor, and generator data

The turbine was manufactured by the S. Morgan Smith Co., Contract TV–55017 (Cherokee), and is of the vertical Francis type. It is rated 41,500 h.p. at 100-foot head at 94.7 r.p.m.

The governor was supplied by Woodward Governor Co. and is the cabinet actuator type.

The generator was supplied by General Electric Co., Contract TV–55015 (Cherokee), and is rated 33,333 kv.-a., 3 ph., 60 c., 13,800 v., 94.7 r.p.m. The machine is equipped with Kingsbury thrust bearing and main and pilot exciters. The combined unit is the vertical shaft type with the thrust bearing located below the generator rotor and guided by two guide bearings, one above the thrust bearing directly under the rotor, and the second in the head cover above the runner.

Method of conducting test

Arrangements were made with the Division of Power Operations to vary the load on the machine as the test required. Tests on the machine were made at the following gate openings: 12, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, and 100 percent. The gate positions were adjusted by manually operating the gate control lever on the governor cabinet.

For obtaining the scroll case differential head on the turbine, a water column manometer of 100 inches was connected to piezometer taps R_1, R_2, R_3, and R_4. The location of these taps is shown on plate 56.

At each gate position readings were made of the manometer. Ten manometer readings of each column were made at each position to insure a correct average reading.

The output of the generator was measured by counting the revolutions of the watt-hour meter located on the main switchboard, a stop watch being used to count the time accurately. Two sets of watt-hour readings were made for each test. The majority of these sets of readings required about 60 seconds. At each test the headwater and tailwater elevations were read simultaneously from the remote indicating gauges located in the control room.

Table 23 shows the main switchboard readings recorded during each test. These tables give the gate position, the time, the generator output, and other data for reference. Tables 24 and 25 show the turbine and governor readings, time, gate openings, piezometer reading, and other information.

Capacity of turbine

At the time the tests were conducted, the gross head was very near 102 feet. To check the turbine capacities against the contract guarantees, the data obtained were reduced to a common basis of 100 feet. The computations are given in table 26.

The unit produced 31,750 kw. at a gross head of 100 feet, at 100 percent gate opening. The discharge at this gate opening was 4,735 c.f.s., and the penstock velocity head was 4.3 feet. For computing the capacities of the turbine, the friction and rack losses, and the velocity head at the outlet of the draft tube are to be deducted from the gross head. The net head manometer gave a head differential of 5.84 feet. The head differential plus the draft tube velocity head minus the penstock velocity head equals 2.4 feet. This gave a net head of 97.6 feet. Therefore, 31,750 kw. at 97.6 feet equals 44,200 hp. at 100-foot net head. The generator efficiency being 97.2 percent, a total of

45,475 hp. at the 100-foot net head is obtained. The guarantee at this head is 41,500 hp. Therefore, 45,475 hp. is 3,975 hp. or 9.58 percent above the contract guarantee.

There are other capacities guaranteed at other heads, and it is felt certain that these will be met if not exceeded.

Operating characteristics

For the purpose of constructing the operating characteristic curves, the data were computed for a gross head of 100 feet. These curves are shown on plate 57.

In computing these data a maximum overall efficiency of 88 percent at 100-foot head was assumed for power delivered at the switchboard. This takes into account generator, turbine, penstock, trashrack, and draft tube losses. The power output varies as the three-halves power of the head and the piezometer deflection varies directly with the head. The figures obtained by dividing the kilowatts by the square root of the piezometer deflection were plotted against the kilowatt output. This gives a curve similar to the efficiency curve. The points as plotted were somewhat erratic. In order to make a smooth curve, the piezometer deflections were plotted against gate opening and a smooth curve drawn through these points. From this curve the piezometer deflections were replotted, which resulted in a smooth curve similar to the efficiency curve. From this curve the maximum point of efficiency was taken and a constant obtained by dividing $\frac{\text{kw}}{\sqrt{R_4-R_3}}$ by 88. Using this constant, the efficiency curve was plotted.

From the efficiency curve the cubic feet per second were computed using the formula $Q=\frac{\text{kw}\times 11.8}{H\times E}$.

Flowmeter calibration

The flowmeters are specified for a total deflection of 100 inches of water. For the purpose of obtaining a constant for the flowmeter, the piezometer taps R_4-R_3 were used. These taps were found to be more reliable than either R_4-R_1 or R_4-R_2 and the deflection in inches was just under 100. The coefficient for the discharge was found to be 1939.5. This constant was obtained by dividing the cubic feet per second at 88 efficiency by $\sqrt{R_4-R_3}$ at this point.

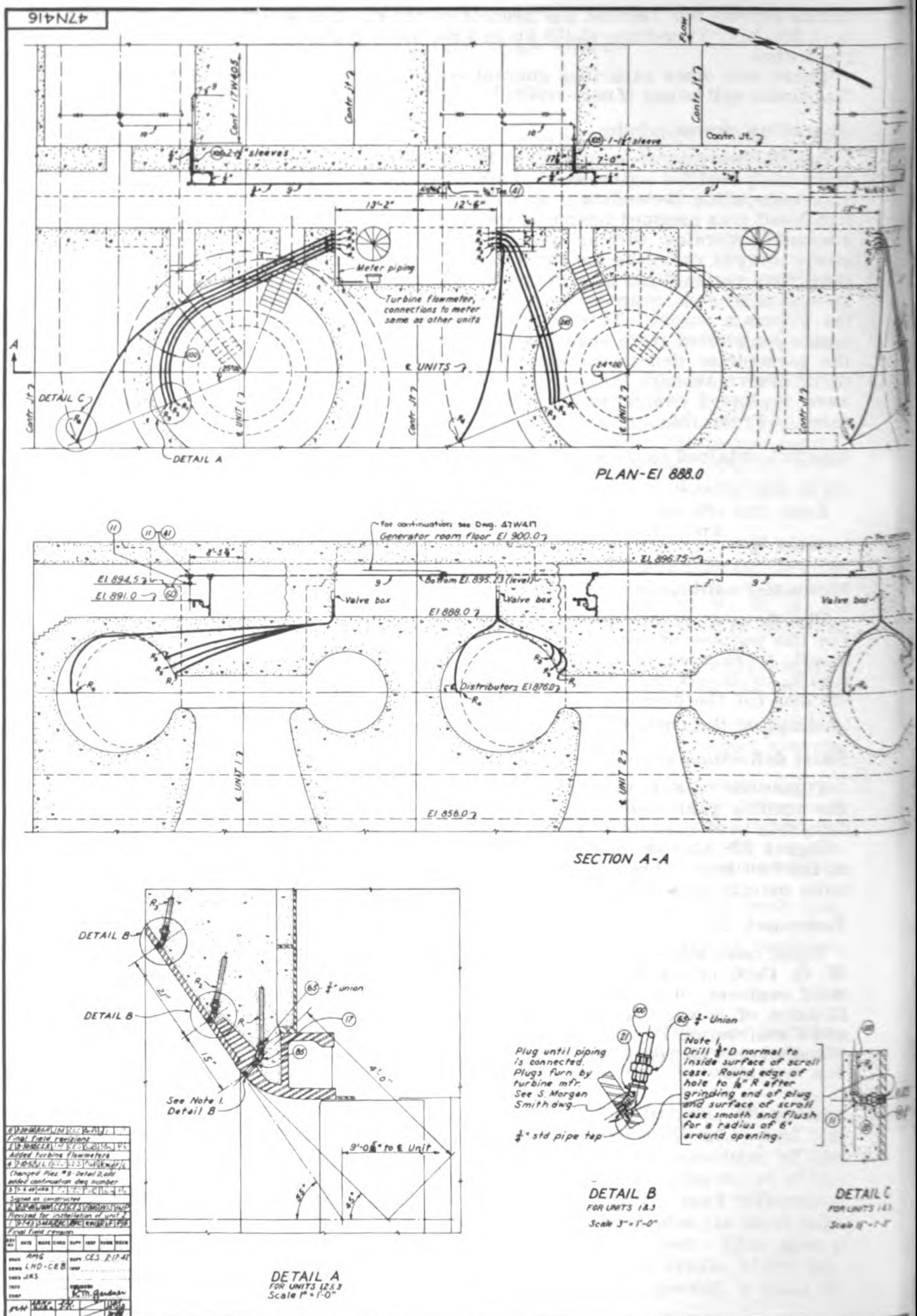
Shaft deflections and oil pressures on wicket gates

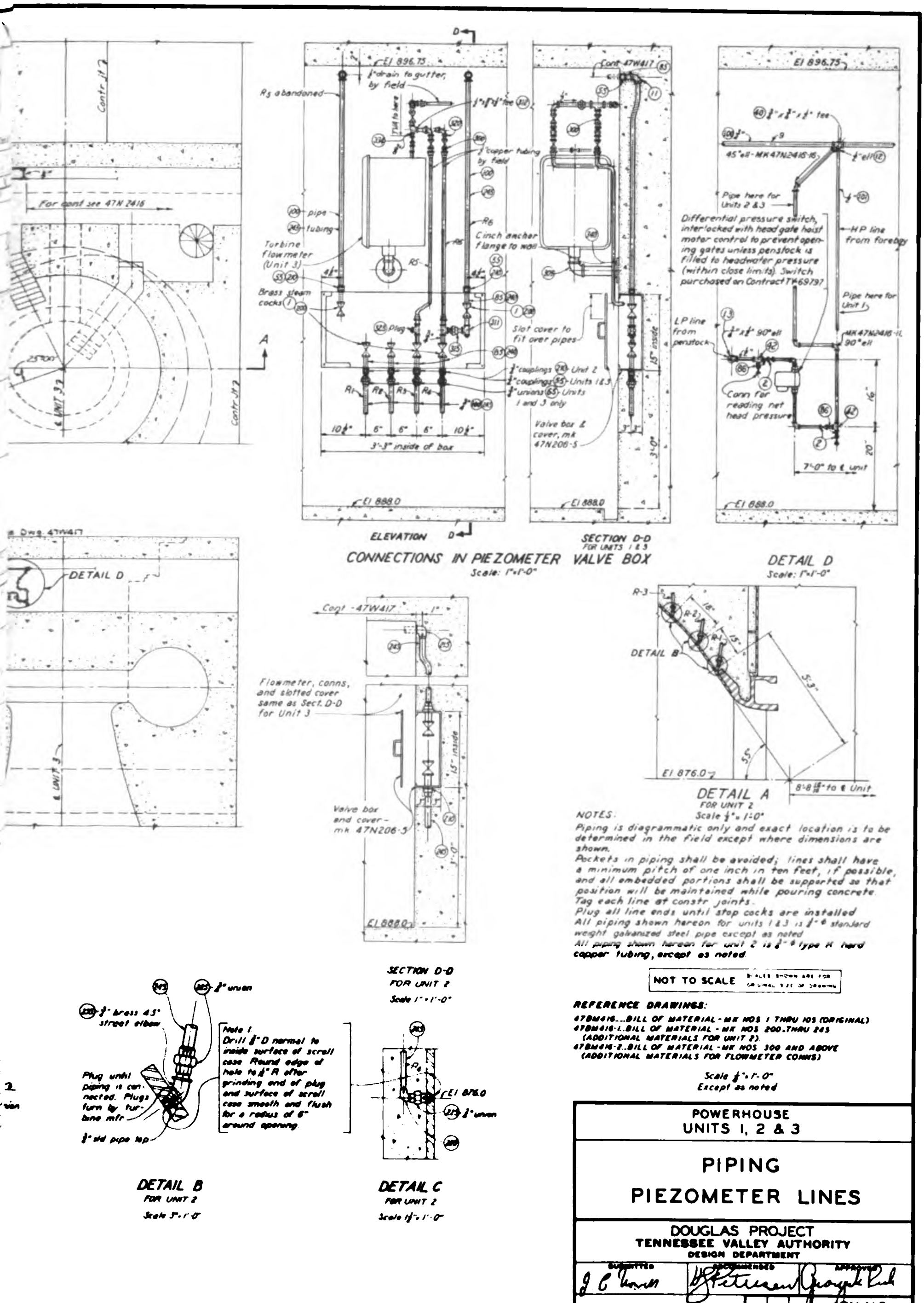
Figure 368 (p. 844) shows the shaft deflections under the thrust bearing and at the turbine guide bearing at different gate openings. These curves show the deflection in all cases to be 4 mills or less.

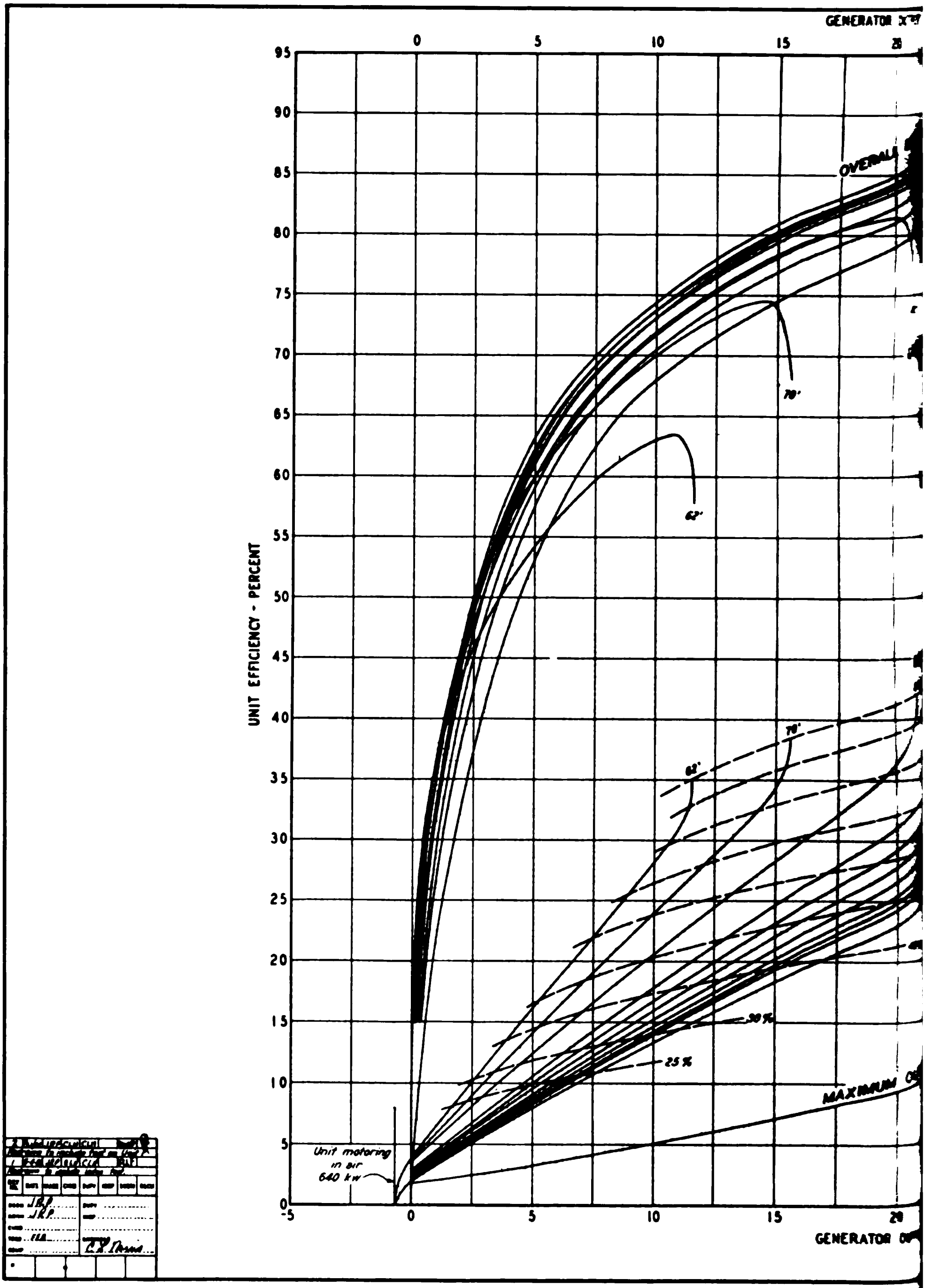
Figure 368 also shows the oil pressures required to operate the wicket gates at 102-foot head. Pressures in all cases were less than 95 p.s.i. which gives a large margin of safety over the 300 p.s.i. which the governors provide.

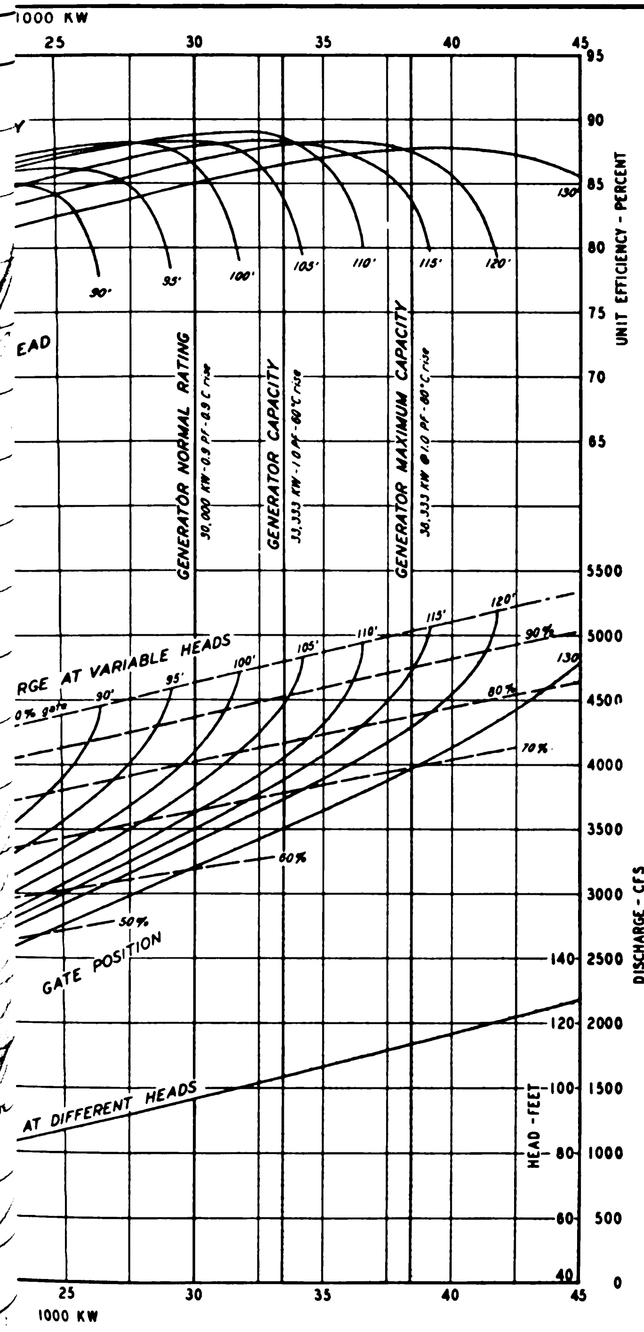
Personnel

These tests were conducted under the supervision of Messrs. C. L. Norris and W. G. Cobb of the TVA Division of Design and Mr. J. D. Scoville, assistant chief engineer, of S. Morgan Smith Co., with assistance from members of the Division of Power Operations under Mr. Robert C. Woltz, and the Engineering and Construction Departments under Messrs. T. F. Taylor, J. S. Lewis, and E. Woodbury. This report was prepared by Mr. J. R. Parrish.


47N416
Flow
Cent-17W405
Centr. Jt.
2-1½" sleeves
1-1½" sleeve
Constr. Jt.
13'-2"
12'-6"
Meter piping
Turbine flowmeter, connections to meter same as other units
℄ UNITS
℄ UNIT 1
℄ UNIT 2
DETAIL C
DETAIL A
PLAN-El 888.0
For continuation see Dwg. 47W417
Generator room floor El 900.0
El 894.5
El 891.0
Bottom El. 895.23 (level)
El 896.75
Valve box
El 888.0
Distributors El 876.0
El 858.0
SECTION A-A
DETAIL B
¾" union
See Note 1. Detail B
9'-0" to ℄ Unit
DETAIL A
FOR UNITS 1,2 & 3
Scale 1" = 1'-0"
Plug until piping is connected. Plugs furn. by turbine mfr. See S. Morgan Smith dwg.
¾" std pipe tap
¾" Union
Note 1. Drill ¾"D normal to inside surface of scroll case. Round edge of hole to ⅛" R after grinding end of plug and surface of scroll case smooth and flush for a radius of 6" around opening.
DETAIL B
FOR UNITS 1 & 3
Scale 3" = 1'-0"
DETAIL C
FOR UNITS 1 & 3
Final field revision
Added turbine flowmeters
Changed Piez #9 - Detail D, add added continuation dwg number
Signed as constructed
Revised for installation of unit 2
Final field revision


ELEVATION
SECTION D-D
FOR UNITS 1 & 3
CONNECTIONS IN PIEZOMETER VALVE BOX
Scale: 1"=1'-0"
DETAIL D
Scale: 1"=1'-0"
DETAIL A
FOR UNIT 2
Scale 1/4"=1'-0"
SECTION D-D
FOR UNIT 2
Scale 1"=1'-0"
DETAIL B
FOR UNIT 2
DETAIL C
FOR UNIT 2
Differential pressure switch, interlocked with head gate hoist motor control to prevent opening gates unless penstock is filled to headwater pressure (within close limits). Switch purchased on Contract TV-69797
Flowmeter, conns, and slotted cover same as Sect. D-D for Unit 3
NOTES:
Piping is diagrammatic only and exact location is to be determined in the field except where dimensions are shown.
Pockets in piping shall be avoided; lines shall have a minimum pitch of one inch in ten feet, if possible, and all embedded portions shall be supported so that position will be maintained while pouring concrete.
Tag each line at constr joints.
Plug all line ends until stop cocks are installed.
All piping shown hereon for units 1 & 3 is 1/2" standard weight galvanized steel pipe except as noted.
All piping shown hereon for unit 2 is 1/2" type K hard copper tubing, except as noted.
NOT TO SCALE
REFERENCE DRAWINGS:
47BM416...BILL OF MATERIAL - MK NOS 1 THRU 105 (ORIGINAL)
47BM416-1..BILL OF MATERIAL - MK NOS 200 THRU 245 (ADDITIONAL MATERIALS FOR UNIT 2)
47BM416-2..BILL OF MATERIAL - MK NOS 300 AND ABOVE (ADDITIONAL MATERIALS FOR FLOWMETER CONNS)
Scale 1/4"=1'-0"
Except as noted
POWERHOUSE
UNITS 1, 2 & 3
PIPING
PIEZOMETER LINES
DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
KNOXVILLE
2-17-42
47N416


GENERATOR
0
5
10
15
20
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
UNIT EFFICIENCY - PERCENT
OVERALL
70'
62'
70'
62'
30%
25%
MAXIMUM
Unit motoring in air 640 kw
-5
0
5
10
15
20
GENERATOR



NOTES:

The following cavitation guarantees should be observed during the first year of operation in order not to void the guarantees.

HEAD-FEET	OUTPUT HORSEPOWER MINIMUM Not more than 800 hours	OUTPUT HORSEPOWER MAXIMUM Do not exceed for more than 50 hrs altogether
130	20,000	50,000
125	20,000	50,000
110	20,000	49,100
100	20,000	41,500
75	20,000	23,000
62	8,500	9,000

Based on experience curves furnished by S. Morgan Smith Co. revised in accordance with data obtained from index tests on Unit 3, 4-2-43 and Unit 1, 1-12-44. Data should be revised to include other field tests of turbines and generators.

TURBINES RATED:
41,500 HP - 100' head - 94.7 rpm - manufactured by S. Morgan Smith Co., York, Pa.

GENERATORS RATED:
33,333 KVA - 3 phase - 60 cycles - 13,800 volts - 0.9 power factor - 60°C rise - 94.7 rpm, manufactured by General Electric Co., Schenectady, N.Y.

PRELIMINARY

OPERATING CHARACTERISTICS
33,333 KVA UNIT

DOUGLAS PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED M. L. Sullivan | RECOMMENDED [signature] | APPROVED George K. Reed

KNOXVILLE 2-20-43 20 M 4 47K220 R2

TABLE 23.—*Switchboard readings*

Time Apr. 2, 1943	Kilo-volts	Gate opening—percent	A.c. amps average	Mega-watts indicated	Mvar	Power factor	Main exciter		Revolu-tions	Time—seconds	Calculated[1] megawatts	Headwater elevation	Tailwater elevation	Net head —ft.
							Volts	Amps.						
A.M.														
1:22	12.6	30	250	6.0	0	1.0	64	375	10	165.0	6.280	973.49	869.63	103.86
1:30	12.5	30	350	7.6	0	1.0	64	375	14	183.4	7.900	973.50	869.74	103.76
1:37	12.6	40	550	12.0	0	1.0	80	400	20	170.2	12.180	973.50	869.92	103.58
1:45	12.5	40	525	11.5	0	1.0	80	400	21	193.2	11.270	973.51	870.15	103.36
1:53	12.6	50	775	17.0	0	1.0	87	430	30	180.0	17.200	973.51	870.44	103.07
2:01	12.6	50	750	16.5	0	1.0	87	430	29	178.8	16.800	973.52	870.55	102.97
2:08	12.5	60	975	21.0	0	1.0	90	450	34	162.6	21.600	973.51	870.66	102.85
2:14	12.6	60	1000	22.0	0	1.0	93	460	38	176.0	22.400	973.51	870.90	102.61
2:22	12.6	70	1225	26.5	0	1.0	101	510	47	181.6	26.800	973.51	871,08	102.43
2:28	12.6	80	1375	30.0	0	1.0	105	525	52	177.0	30.400	973.51	871.42	102.09
2:36	12.6	90	1450	31.5	0	1.0	111	550	55	177.2	32.100	973.52	871.60	101.92
2:44	12.5	100	1475	32.0	0	1.0	113	560	57	181.0	32.600	973.52	871.73	101.79
2:50	12.5	95	1475	31.5	0	1.0	113	560	56	178.8	32.500	973.52	871.75	101.77
2:57	12.6	85	1425	30.5	0	1.0	110	540	54	178.8	31.400	973.53	871.71	101.82
3:08	12.5	75	1325	28.2	0	1.0	105	520	48	172.5	28.800	973.53	871.66	101.87
3:15	12.5	65	1125	24.0	0	1.0	100	490	42	178.2	24.400	973.54	871.52	102.02
3:21	12.5	55	875	19.0	0	1.0	91	445	34	180.8	19.500	973.54	871.33	102.21
3:29	12.5	45	625	13.5	0	1.0	85	410	24	178.8	13.900	973.54	871.06	102.48
3:33	12.5	45	640	13.8	0	1.0	83	405	24	177.0	14.000	973.54	870.93	102.61
3:39	12.5	35	440	9.7	0	1.0	79	390	17	181.2	9.700	973.55	870.78	102.77
3:45	12.4	25	275	5.5	0	1.0	77	380	10	182.8	5.700	973.56	870.38	103.18

[1] Calculated megawatts $= 115.2 \times \frac{\text{revolutions}}{\text{seconds}}$

TABLE 24.—*Operating cylinder pressures*

Time Apr. 2, 1943	Gate opening—percent	Opening side—p.s.i.	Closing side—p.s.i.	Difference—p.s.i.	Gates moving	Remarks
A.M.						
1:30	30–40	190	140	50	Open	Valve open.
		190	137	53	do	Do.
		195	135	60	do	Do.
		205	145	60	do	Do.
		210	150	60	do	Do.
1:45	40–50	215	150	65	do	Do.
		205	130	75	do	Valve closed.
		207	130	77	do	Do.
		209	135	74	do	Do.
		210	130	80	do	Do.
2:05	50–60	210	130	80	do	Do.
		205	125	80	do	Valve open.
		204	120	84	do	Do.
		205	120	85	do	Do.
		206	118	88	do	Do.
2:15	60–70	208	118	90	do	Do.
		218	125	93	do	Valve closed.
		220	125	95	do	Do.
		220	125	95	do	Do.
		218	125	93	do	Do.
2:20	70–80	217	124	93	do	Do.
		212	120	92	do	Do.
		215	120	95	do	Do.
		213	120	93	do	Do.
		210	121	89	do	Do.
2:30	80–90	210	124	86	do	Do.
		205	120	85	do	Do.
		204	116	88	do	Do.
		203	120	83	do	Do.
		201	125	76	do	Do.
2:40	90–100	200	125	75	do	Do.
		195	125	70	do	Do.
		198	130	68	do	Do.
		194	135	59	do	Do.
		190	135	55	do	Do.
2:45	100–95	190	135	55	do	Do.
		180	150	30	Closed	Do.
		180	150	30	do	Do.
2:50	95–85	185	150	35	do	Do.
		180	145	35	do	Do.
		185	145	40	do	Do.
		184	145	39	do	Do.
		185	142	43	do	Do.
2:55	85–75	185	145	40	do	Do.
		183	140	43	do	Do.
		185	135	50	do	Do.
		186	135	51	do	Do.
		186	135	51	do	Do.
3:05	75–65	188	135	53	do	Do.
		185	135	50	do	Do.
		185	130	55	do	Do.
		190	135	55	do	Do.
		190	135	55	do	Do.
3:15	65–55	190	135	55	do	Do.
		195	140	55	do	Do.
		195	140	55	do	Do.
		195	145	50	do	Do.
		195	145	50	do	Do.
3:20	55–45	195	145	50	do	Do.
		185	140	45	do	Do.
		190	140	50	do	Do.
		190	145	45	do	Do.
		187	145	42	do	Do.
3:30	45–35	186	145	41	do	Valve open.
		175	140	35	do	Do.
		175	145	30	do	Do.
		175	150	25	do	Do.
		175	150	25	do	Do.
3:35	35–25	172	150	22	do	Do.
		165	150	15	do	Do.
		164	150	14	do	Do.
		164	150	14	do	Do.
		163	152	11	do	Do.
3:45	25–12	163	155	8	do	Do.
		165	160	5	do	Do.
		160	165	5	do	Do.
		162	170	8	do	Do.
		160	170	10	do	Do.
3:55	12	145	165	20	do	Do.

TABLE 25.—*Turbine and piezometer readings*

Time Apr. 2, 1943	Gate opening, percent	Shaft throwout—in.		Air valve	Head cover		Net head piezometer—ft.	Feet of water			Gross head—ft.
		Under thrust bearing	Turbine guide bearing		Pressure—ft.	Vacuum—ft.		R_4-R_1	R_4-R_2	R_4-R_3	
1:20	30	0.004	0.002	Closed		6.5	0.421	0.645	0.597	0.421	103.86
1:30	30	.004	.002	Open		3.0	.487	.696	.633	.446	103.76
1:40	40	.004	.002	do		3.0	.738	1.304	1.239	.855	103.58
1:45	40	.004	.002	Closed		6.5	.967	1.321	1.245	.896	103.36
1:55	50	.003	.002	do		6.0	1.401	2.339	2.198	1.517	103.07
2:05	50	.003	.002	Open		2.0	1.572	2.304	1.978	1.414	102.97
2:10	60	.002	.002	do		1.5	2.259	3.457	3.250	2.245	102.85
2:15	60	.002	.002	Closed		11.0	2.397	3.716	3.243	2.292	102.61
2:20	70	.002	.002	do		7.0	3.264	5.023	4.670	3.278	102.48
2:30	80	.002	.002	do	0	0	4.298	6.549	6.141	4.362	102.09
2:40	90	.002	.002	do	4.0		5.088	7.786	7.352	5.218	101.92
2:45	100	.003	.002	do	9.5		5.943		8.373	6.001	101.79
2:50	95	.002	.002	do	8.0		5.516		7.822	5.554	101.77
2:55	85	.002	.002	do	2.0		4.695	7.102	6.664	4.857	101.82
3:05	75	.002	.002	do		3.5	3.794	5.753	5.298	3.838	101.87
3:15	65	.003	.002	do		8.0	2.79	4.296	3.679	2.806	102.02
3:20	55	.003	.002	do		13.0	1.734	3.256	2.245	1.731	102.21
3:25	45	.003	.002	do		10.0	1.199	1.766	1.377	1.011	102.48
3:30	45	.003	.002	Open		2.0	1.101	1.675	1.498	1.061	102.61
3:35	35	.003	.002	do		3.0	.586	.945	.872	.622	102.77
3:45	25	.003	.002	do		5.0	.197	.437	.406	.289	103.18
3:55	12	.003	.002	do		6.0	.039	.042	.031	.028	

TABLE 26.—*Calculations*

Gate position, percent	Gross head—ft.	Generator output, kw.	Feet of water			Corrected to 100-foot head				Corrected to 100-foot head from smooth curve			Efficiency	Cubic feet per second, R_4-R_3
			R_4-R_1	R_4-R_2	R_4-R_3	Generator output—kw.	Feet of water, R_4-R_3	$\sqrt{R_4-R_3}$	$\frac{Kw}{\sqrt{R_4-R_3}}$	Feet of water, R_4-R_3	$\sqrt{R_4-R_3}$	$\frac{Kw}{\sqrt{R_4-R_3}}$		
25	103.18	5,700	0.437	0.406	0.289	5,435	0.28	0.529	10,270	0.252	0.502	10,820	65.8	970
30	103.78	7,900	.696	.633	.446	7,470	.43	.656	11,380	.426	.6525	11,450	69.6	1,265
35	102.77	9,700	.945	.872	.622	9,330	.605	.778	11,970	.600	.7745	12,050	73.2	1,505
40	103.58	12,180	1.304	1.239	.855	11,550	.826	.909	12,700	.837	.915	12,620	76.75	1,775
45	102.61	14,000	1.675	1.498	1.081	13,460	1.053	1.026	13,120	1.06	1.028	13,080	79.45	2,000
50	103.07	17,200	2.339	2.198	1.517	16,440	1.472	1.214	13,540	1.472	1.214	13,540	82.3	2,360
55	102.21	19,500	3.256	2.245	1.731	18,860	1.693	1.301	14,500	1.872	1.369	13,780	83.8	2,660
60	102.61	22,400	3.716	3.243	2.292	20,800	2.233	1.495	13,910	2.2	1.484	14,010	85.2	2,825
65	102.02	24,400	4.296	3.679	2.806	23,680	2.75	1.658	14,270	2.76	1.661	14,250	86.6	3,225
70	102.43	26,800	5.023	4.670	3.278	25,850	3.20	1.789	14,450	3.21	1.791	14,430	87.75	3,475
73						27,500	3.61	1.900	14,470	3.61	1.9	14,470	88.0	3,685
75	101.87	28,800	5.753	5.293	3.838	28,030	3.767	1.941	14,440	3.76	1.938	14,460	87.9	3,765
80	102.09	30,400	6.549	6.141	4.362	29,500	4.275	2.068	14,250	4.26	2.062	14,300	86.95	4,005
85	101.82	31,400	7.102	6.664	4.857	30,560	4.77	2.185	13,850	4.76	2.18	14,010	85.2	4,230
90	101.92	32,100	7.786	7.352	5.218	31,200	5.12	2.264	13,770	5.21	2.283	13,660	83.0	4,435
95	101.77	32,500		7.822	5.554	31,650	5.46	2.339	13,520	5.68	2.382	13,280	80.75	4,625
100	101.79	32,600		8.373	6.001	31,750	5.89	2.427	13,020	5.95	2.439	13,020	79.1	4,735

$$\text{Efficiency coefficient} = \frac{\dfrac{Kw.}{\sqrt{R_4-R_3}}}{88.0} = 164.3$$

$$\text{Discharge coefficient} = \frac{Q \text{ at } 88.0\ E}{R_4-R_3} = 1939.5$$

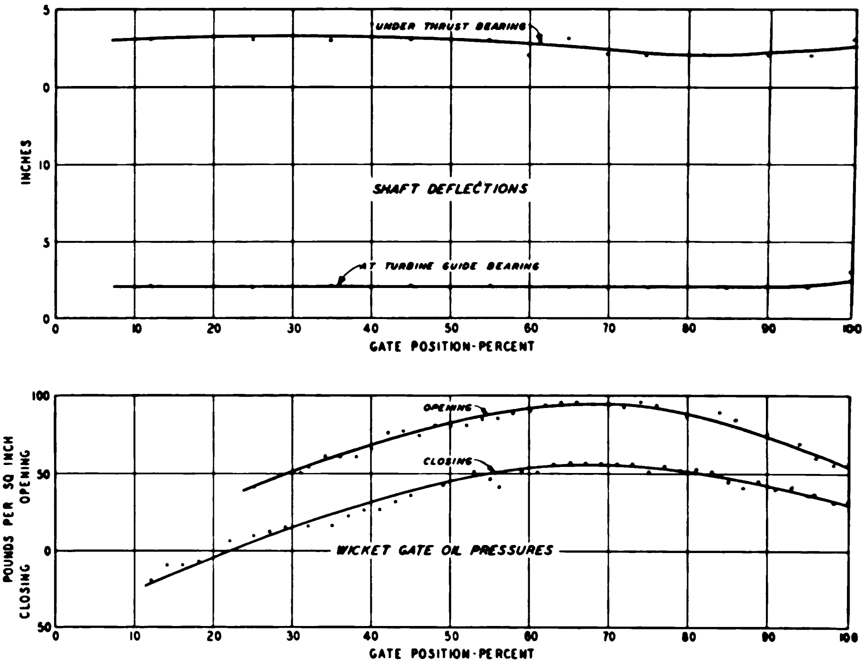


FIGURE 368.—*Shaft deflections and wicket gate oil pressures—Douglas unit 3 tests.*

LOAD REJECTION TEST REPORT—UNIT NO. 4, DOUGLAS PROJECT

(Reference charts not included in this report)

Upon the completion of the various preliminary checks and adjustments of unit 4 and following the completion of the mechanical and heat runs of the machine, load rejection tests were made to determine operating characteristics of the governor itself, the associated governor equipment, the voltage regulator, and miscellaneous associated equipment. This report is concerned with the behavior of the governor equipment and includes charts of wicket gate movement and timing, governor performance as a result of various combinations of adjustments, and other correlated data. The charts were obtained by using a laboratory-built selsyn recorder to record wicket gate movement and an Esterline-Angus wide-range frequency recorder. During the load rejection and gate timing tests a chart speed of 12 inches per minute was used, and on the governor adjustment tests the chart speed was 3 inches per minute.

This machine is equipped with remote control facilities, and the governor and all auxiliary equipment was given complete operational checks before the machine was started initially.

On the gate timing tests which are recorded on charts 1 and 2, the governor was set to open the gates from 0 to 100 percent in 6 seconds. The closing time was set for 8 seconds from 100 to 0 percent, including the cushioning effect at the end of the closing stroke.

Charts 3 through 11 record off-line governor performance as to stability and recovery following various combinations of adjustments.

Charts 12 and 13 record governor performance following quick changes of speed droop with speed adjustment held constant. Chart 14 records governor performance following quick changes of speed adjustment with speed droop held constant.

The load rejection tests were made at ¼, ½, ¾ and full generator loading and are recorded on charts 15, 16, 17, and 18.

The family of curves on chart 19 were drawn from data obtained from additional off-line and on-line tests.

The off-line tests were made by selecting various predetermined frequency values and recording speed adjustment dial readings and gate positions with speed droop settings of 0, 2.5, 5, and 6 percent. Due to fluctuating tailwater conditions the gate position readings are of doubtful value. The data obtained from these tests are presented in the following:

NAME PLATE DATA

Generator

General Electric Co., type ATI 80
Kva 28,888, volts 13,800, amperes 1208
Power factor 90 percent, 3 phase, 60 cycles, 90 rpm
Exciter amperes 750, exciter volts 250
Serial No. 6920391

Main exciter

General Electric Co., type EV
Kw 220, volts 250, amperes 880, rpm 90
Serial No. 7110310

Pilot exciter

General Electric Co., type EV
Kw 17, amperes 68, rpm 90
Serial No. 7110311

Turbine

S. Morgan Smith
Francis type wheel
Hp 35,500, head 80 feet, rpm 90
Serial No. 9529

Actuator

Woodward Governor Co., cabinet type
Serial No. 294013

Permanent magnet generator

Woodward Governor Co.
Rpm 90, cycles 9, 3 phase
Full load amperes 1, full load volts 76, no load volts 90
Serial No. 294013

Speed adjustment motor

Bodine Electric Co., type NSE 13 RG
Volts 250 dc, amperes 0.13, rpm 5,000, hp 1/80
Gear ratio 180 : 1
Serial No. 2452729

DATA ON LOAD REJECTION TESTS

Item				
Gate position, percent—At time of test	27	38	51	65
Gate position, percent—Minimum	8	1	0	0
Frequency—System	60.04	60.08	60.05	60.04
Frequency—Maximum	63.40	66.80	72.50	80.00
Frequency—Floating over	60.50	61.00	61.40	61.85
Rpm—Maximum (tachometer)	95	100	107	120
Rpm—Floating over (tachometer)	91	92	93	94
Megawatts	7	12.5	19.5	25.5
Speed adjustment (dial reading)	S-1.20	S-0.57	F-0.13	F 0.88
Time—Aug. 2, 1954	1:49 p.m.	2:04 p.m.	2:28 p.m.	2:45 p.m.
Forebay elevation	962.61	962.58	962.62	962.62
Tailwater elevation	873.53	873.44	873.43	873.76
Effective head—feet	89.08	89.14	89.19	88.86
Percent speed droop for % gate being used (calculated)	0.766	1.531	2.248	3.011
Percent speed droop for 100% gate (calculated)	5.1	5.88	5.77	5.68

Governor settings:

Restoring arm ratio	40:1
Needle valve	⅜turn
Compensation	100%
Speed droop dial—S.N.L	5%
Gate position—S.N.L	12%
Speed adjustment—S.N.L	S 2.08

OFF-LINE TESTS

Percent speed droop	Speed adjustment	Frequency	Percent gate position
6	S-9.50	55.0	10.5
6	S-6.12	57.5	11.5
6	S-2.33	60.0	12.0
6	F-2.00	62.5	13.5
6	F-7.20	65.0	15.0
5	F-7.68	65.0	15.0
5	F-2.32	62.5	14.0
5	S-2.08	60.0	12.0
5	S-5.80	57.5	11.5
5	S-9.43	55.0	10.5
2.5	S-8.66	55.0	10.5
2.5	S-5.26	57.5	11.5
2.5	S-1.5	60.0	12.5
2.5	F-2.81	62.5	13.5
2.5	F-8.26	65.0	15.0
0	(max.) F-9.18	65.0	15.0
0	F-4.10	62.5	14.0
0	S-0.19	60.0	12.5
0	S-3.94	57.5	11.5
0	S-7.54	55.0	10.5

The data listed below were obtained by keeping the speed adjustment constant and varying the speed droop setting over its entire range:

Percent speed droop	Speed adjustment	Frequency
0	S-2.08	58.80
1	S-2.08	59.15
2	S-2.08	59.40
3	S-2.08	59.66
4	S-2.08	59.90
5	S-2.08	60.00
6	S-2.08	60.15

The data listed below were obtained after paralleling the machine with the system and operating it at ¼, ½, ¾, and full load. At each of these loadings the speed droop settings were changed to the various values shown in the table and the respective speed adjustment settings and gate positions were recorded.

ON-LINE TESTS

Percent speed droop	Speed adjustment	System frequency	Percent gate opening	Megawatts
6	S-2.16	60.01	12	0
6	S. 1.26	60.01	27	7
6	S-0.52	60.01	38	12.5
6	F-0.33	60.01	51	19.5
6	F-1.23	60.01	65	25.5
5	S-2.08	60.04	12	0
5	S-1.20	60.04	27	7
5	S-0.57	60.06	38	12.5
5	F-0.13	60.05	51	19.5
5	F-0.88	60.04	65	25.5
3.5	S-1.63	60.01	12	0
3.5	S-1.12	60.02	27	7
3.5	S-0.68	60.02	38	12.5
3.5	S-0.18	60.02	51	19.5
3.5	F-0.32	60.02	65	25.5
2	S-1.06	60.02	12	0
2	S-0.79	60.02	27	7
2	S-0.54	60.02	38	12.5
2	S-0.30	60.02	51	19.5
2	F. 0.02	60.02	65	25.5

It was necessary to bypass the intermittent brake application feature of the automatic brake timer on this unit due to the short stopping time. After the initial application of the brakes at half speed (45 rpm) the machine stops in 30 seconds with high tailwater and in 50 seconds with low tailwater conditions. Several stopping tests with continuous brake application resulted in little or no temperature rise in the brake shoes.

The conclusions reached from these tests are:

1. The operation of the governor equipment is satisfactory and equals that of similar units with respect to off-line regulation and recovery response.
2. The unit performs satisfactorily under load and is acceptable for system operation.

CONSTRUCTION SPECIFICATION NO. FL–HYDR–653—FIELD ERECTION OF HYDRAULIC KAPLAN TURBINES, ALIGNMENT OF TURBINE AND GENERATOR SHAFTS, FINAL TEST OF TURBINES AND GOVERNORS, FORT LOUDOUN PROJECT

(Reference drawings not included in this report)

SEC. 1. *General scope.*—This outline covers field erection of the embedded parts, concreting these parts in, the erection of the rotating and fixed internal parts of the hydraulic turbines, and the alignment of the turbine and generator shafts for Fort Loudoun powerhouse, the erection of the governors, and preliminary test of governors and turbines.

The turbines will be erected under the supervision of an erecting engineer of the turbine contractor, the Baldwin Southwark Division of the Baldwin Locomotive Works.

The governors will be furnished by the Woodward Governor Co., under a separate contract, and will be erected under the supervision of the Authority's forces. Final adjustments and connections of the governor will be made under the supervision of an erection engineer of the Woodward Governor Co.

Allis-Chalmers Manufacturing Co. will furnish all necessary tools and equipment, labor and supervision, and will be responsible for erection of the generators.

The above contractors have been consulted in the preparation of this outline, and it is intended to serve only as a convenient summary of standard field erection practice and does not attempt to preclude alternate methods of accomplishing the desired results.

The erection work covered by this outline is to be witnessed and checked by TVA. Complete and accurate records of all pertinent setting, fits, and alignments shall be prepared and certified by TVA and the erecting engineers of the contractors.

SEC. 2. *Reference drawings and specifications.*—Field instructions for placing concrete around the turbine parts are covered in detail in instructions dated July 17, 1942, entitled "Instructions for Concrete Placing—Powerhouse Substructure—Second Stage Construction."

The following drawings are referred to:

TVA Drawings

1. 41N213Ro—Concrete—Stay Ring, Throat Ring and Draft Tube Liner—Setting—Outline and Reinforcing
2. 41N216, –217, –218, and –219—Concrete—Scroll Case Roof—Outline

Contractor's Drawings

1. 35226—Details of Draft Tube Liner
2. 35228—Details of Stay Ring
3. 35227—Plan of Stay Ring
4. 35229—Details of Throat Ring
5. 34758—Details of Lower Pit Liner
6. 35230—Details of Upper Pit Liner
7. 35231—Details of Distributor Ring
8. 35357—Details of Outer Head Cover
9. 35358—Details of Inner Head Cover

10. 35232—Details of Head Cover Barrel
11. 35251—Details of Lifting Arrangement
12. 35260—Details of Main Shaft
13. 35233—Stuffing Box Details
14. 35266—Method of Supporting Piston Rod during Erection
15. 35276—Details of Jacking Devices and Special Wrenches
16. 35421—Details of Piston Cap and Pipe Head Nut

SEC. 3. *Setting draft tube liner.*—Details of the draft tube liner are shown on Baldwin Southwark's drawing 35226. Concrete will be carried up, including the outside walls of the scroll case with piers ending at elevation 728.5, on which to erect the stay ring.

A recess approximately 6 feet larger in diameter than the draft tube liner will be left. The bottom of this recess will be at various elevations, sloping generally from downstream to upstream, upon which the liner is to be supported.

First place a temporary platform near the bottom of the recess within working reach of the different elevations on which the liner is to rest. Due to the fact that this recess is smaller in diameter at the top than at the bottom of the draft tube liner, the bottom sections will have to be erected in place. The top section may be erected in place or assembled outside and placed as a unit on the lower sections.

The liner shall be supported by short sections of small beams or channel or concrete blocks, and adjusted for height by iron wedges, all blocking and wedges being furnished by TVA.

The liner shall be properly aligned and held rigidly in place by the anchor rods and turnbuckles provided by the contractor.

The vertical alignment shall be correct within $\frac{1}{16}$ of an inch and the horizontal alignment shall be corrected within $\frac{1}{32}$ of an inch. All welding shall be done prior to placing concrete.

After the liner is properly set, checked and welded, concrete may be placed up to elevation 719.75. Care shall be taken in placing concrete so that unequal pressure around the liner does not distort and push the liner out of place. The rate of placing should not exceed 1 foot vertically per hour. The concrete shall be thoroughly spaded and rodded, and no mechanical vibrators may be used. Periodic alignment checks shall be made on the liner during concrete placing.

Water shall be sprayed on the inside surface of the liner during concreting and for a period of seven days afterwards. Water shall be kept flowing constantly and care should be taken that the supply will not be cut off during this period.

SEC. 4. *Setting stay ring.*—The stay ring will consist of four sections, each section weighing approximately 43,000 pounds. Details are shown on Baldwin Southwark's drawings 35228 and 35227. Each section shall be set upon the erection piers provided. Thirty-ton screw jacks and proper hold-down bolts are provided by the contractor for proper alignment of the stay ring. Each section shall be properly aligned and leveled before the next section is placed. This will result in much less work in installing the last section, and less alignment work after all sections are installed. The stay ring shall be made as nearly round as possible and shall be set from a piano wire which supports a heavy plumb suspended in oil. This wire shall be located on the same lines as the center of the draft tube liner at elevation 723.52.

The top section of the stay ring shall be braced inside by a heavy pipe spider, and the outside shall be braced from the scroll case walls by heavy pipe struts. The struts shall be opposite the spider legs on the inside of the ring.

The scroll case roof forms shall be so made that they will be self-supporting and shall not touch the speed ring by a minimum of $\frac{1}{4}$ inch. When the concrete is placed in these forms, they will swell and if allowed to touch the stay ring will push the ring out of alignment.

SEC. 5. *Setting throat ring.*—The throat ring will consist of two half sections, each half weighing approximately 52,000 pounds. Details of this are shown on Baldwin Southwark's drawing 35229. With the stay ring and the draft tube liner in alignment, the outer flange of the throat ring will rest on the inside lower flange of the stay ring and the lower portion of the throat ring will extend down around the outside of the draft tube liner. The setting of the draft tube liner and the stay ring will determine how well the throat ring fits the assembly.

If enough crane capacity is available, the throat ring may be assembled outside and set in place as one piece. If crane capacity is not available, each half section will have to be placed separately and the two half sections bolted together in the pit. Care should be taken to make sure that the two vertical joints are drawn tight together.

The lower skirt of the throat ring will extend down over the top of the draft tube liner by approximately 6 inches. The throat ring will be drilled for 254 1-inch rivets, but the draft tube liner will be blank.

With the throat ring resting on the stay ring, center it about a piano wire which is centered in the stay ring, then bolt to the stay ring but do not dowel at this time. With an accurate machinist level, check the horizontal surface on top of the throat ring at elevation 730.73. This surface should be sloping from the center to the outside by approximately 0.010 inch after the throat ring is set, but before the riveting and welding is done. With the throat ring resting on the stay ring, it may be necessary to install pipe struts from the concrete around the draft tube liner at elevation 719.75 to the lower flange of the throat ring at elevation 723.69, to support a part of the weight and to prevent the ring from settling and shrinking when the riveting and welding is done.

After the throat ring has been set and aligned with the stay ring and the draft tube liner, drill rivet holes in the top of the liner using the factory drilled holes in the throat ring as a template. After the holes are drilled, raise the throat ring clear of the top of the draft tube liner and clean all holes of any burrs and remove chips from between the two pieces. Set the throat ring back into place, bolt 50 percent, or more if necessary, to pull up, then ream and countersink the rivet holes. After riveting the throat ring to the draft tube liner, place weld as shown on the throat ring drawing No. 35229. This welding shall be done before concrete is placed on the outside. Grinding and painting may be done at a later date.

Check throat ring for concentricity and for centering with each flange of the stay ring. When centering is correct, dowel the top flange of the throat ring to the lower flange of the stay ring.

SEC. 6. *Concreting stay ring, throat ring and draft tube liner.*—Concrete may now be placed around the throat ring and under the lower ring of the stay ring. Extreme care should be exercised in placing this concrete to insure a good foundation under the stay ring.

The stay ring and the throat ring each have ¾-inch weep holes to allow excess water to escape. The upper portion of this foundation pour will have to be placed through the 4-inch cored holes in the stay ring and the 3-inch drilled holes in the throat ring. These holes should be piped up or boxed up so that a head of approximately 5 feet can be left on the fresh concrete until the initial set has taken place. Small vibrators 2 inches or less in diameter may be used through the pipes or boxes to help in placing the concrete. Rodding through all holes should continue until concrete quits bleeding. This will remove all excess water and the concrete will shrink less with less water. Flowing water shall be kept on the inside surface of the throat ring during this pour and for seven days afterward. Care shall be taken that this cooling water is not shut off during this period.

SEC. 7. *Setting the upper and lower pit liners.*—The pit liners may or may not be set before the concreting is placed under the stay ring. The lower pit liner is shown on Baldwin Southwark's drawing No. 34758. The upper pit liner is shown on their drawing No. 35230.

The lower pit liner will consist of four sections, the total weighing approximately 45,000 pounds. These shall be set on the top ring of the stay ring and bolted with the bolts provided. The liner shall be centered about a piano wire which shall be located in the center of the throat ring as set. Care shall be taken to set the face of the servomotor bases as nearly correct as possible.

The upper pit liner is to be placed on the top flange of the lower liner, aligned with the lower liner and welded. The radius of the top of the upper liner should be held within ¼ inch of drawing dimensions.

SEC. 8. *Placing scroll case baffle concrete.*—This pour forms the end of the scroll case spiral and extends from the bottom to the top of the stay ring. Before this pour is made, continuous water-cooled pipes shall be placed vertically in the pour so that a continuous stream of water may flow during the

pouring and setting of this concrete. This water shall be kept flowing during the pour and for 7 days afterwards.

The rate of pouring shall not exceed 1 foot vertically per hour.

SEC. 9. *Placing scroll case roof concrete.*—Concrete forming the scroll case roof shall be placed in accordance with TVA drawings Nos. 41N216, 41N217, 41N218, and 41N219.

The stay ring and throat ring alignment shall be checked immediately after each pour until the last pour which touches the upper pit liner has been placed. The inside of the pit liners shall be kept cooled with flowing water during the pouring and for 7 days after the last pour.

SEC. 10. *Installing distributor ring, guide vanes and outer head cover.*—The distributor ring consists of four sections, each section weighing approximately 7,000 pounds. The distributor ring contains the bushings for the lower end of the wicket gate trunnions, and is shown on Baldwin Southwark's drawing No. 35231.

Assemble the distributor ring on the flat surface on top of the throat ring, adjust to unit center lines and bolt down, but do not dowel. The ring will have to be assembled in the pit since the upper pit liner is smaller in diameter than the ring. Next assemble the outer head cover on the top flange of the stay ring. The head cover will have to be assembled in the pit also, since it is too large in diameter to pass through the pit liner.

The outer head cover shown on Baldwin Southwark's drawing No. 35357 will consist of four sections, each section weighing approximately 23,000 pounds. The head cover contains the bushing for upper part of the wicket gate trunnions. After the four sections are bolted together and set to the unit center lines, center it about a piano wire which is centered in the throat ring. After centering, bolt the outer head cover to the stay ring but do not dowel.

With the distributor ring and the outer head cover centered, the wicket gate trunnion bushings should fall one directly over the other. In order to make sure this is the case, a mandrel having the same diameter as the wicket gate trunnions shall be inserted in each set of bushings. The mandrel shall turn freely, one man should be able to turn the mandrel. If the mandrel does not turn freely, it may be necessary to revolve the distributor ring. All efforts possible should be made to make the proper alignment before scraping the bushings is resorted to.

After the alignment is complete and the mandrel has been tried in each set of bushings, the distributor ring and the head cover should be doweled. Use undersize dowels on the head cover, one dowel in each ¼ section will be sufficient. After the doweling of head cover, remove the bolts and dowels. Raise the head cover up and support on timbers approximately 6 feet long. This is necessary in order to install the wicket gates. Set the wicket gates in place and lower the outer head cover over the upper end of the gate trunnions, replace holddown bolts and dowels. Check wicket gates to see if they will open and close and seal in the closed position. When alignment is correct, bolt and dowel the head cover using the full number of full size dowels.

SEC. 11. *Installing inner head cover and head cover barrels.*—The inner head cover is shown on Baldwin Southwark's drawing No. 35358. It consists of two sections, each section weighing approximately 45,000 pounds. The two half sections shall be bolted together and placed on and bolted to the head cover barrel. The head cover barrel is shown on Baldwin Southwark's drawing No. 35232 and it consists of one piece which weighs approximately 23,000 pounds.

The head cover and barrel assembly when completed will weigh approximately 113,000 pounds. For setting this assembly in the pit, use the lifting arrangement shown on Baldwin Southwark's drawing 35251. When the assembly is resting on the outer head cover flange, center the head cover barrel bore about a piano wire which is centered in the throat ring. After centering, bolt and dowel to outer head cover.

SEC. 12. *Installing turbine shaft and piston rod.*—Turbine shaft is shown on Baldwin Southwark's drawing No. 35260 and weighs approximately 66,000 pounds. Up-end the shaft using the special lifting device furnished by Baldwin Southwark. Lower the shaft through the head cover barrel and while the shaft still rests on the crane, install the stuffing box shown on Baldwin Southwark's drawing 35233. This consists of two sections, each section weigh-

ing approximately 2,800 pounds. These sections will have to be handled by hand and provisions should be made to attach chain hoist to the top of the shaft to facilitate handling. After the stuffing box is in place, lower the turbine shaft until the shoulder provided on the shaft engages the ledge on the stuffing box.

Plumb the shaft and set central in the head cover barrel. Lift the piston rod and insert it in the turbine shaft, lower it into place and support by special supporting device shown on Baldwin Southwark's drawing No. 35266.

SEC. 13. *Assembling the turbine runner.*—The runner hub and blades will come assembled. The runner assembly will weigh approximately 190,000 pounds. Place the runner assembly (without upper and lower runner caps) on pedestals and foundation plate shown on drawing 35265. Block the runner blades in closed position by means of about 8- by 8-inch props from the floor to the under side of the runner blades. Remove the locking device pieces 6, 9, and 10 which are detailed on drawing 35239 and shown on assembly drawing 35257. These parts are used for shipping and also for centering cross head.

SEC. 14. *Installing runner, shaft, and head covers in the pit.*—Remove the inner head cover, head cover barrel, turbine shaft and piston rod from the pit and place this assembly on the turbine runner. Lower the assembly until the weight of the shaft rests on the runner hub. Remove the stuffing box and raise the inner head cover and head cover barrel until enough clearance is obtained to bolt the shaft to the runner hub. These bolts shall be accurately measured from face of shaft flange to tops of bolts, and after tightening the nuts these lengths shall be increased from 0.006 inch to 0.008 inch. All bolts shall be stressed an equal amount. When shaft and hub are coupled, lower head cover and install stuffing box. Use jacking device drawing 35276 for jacking piston rod and cross head in place. Place nut piece 2, drawing 35258, on piston rod piece 1 and tighten in place with socket wrench piece 11. Be sure that bottom shoulder on piston rod is drawn up tight in cross head by actual measurement, then place nut locking plate, drawing 35253–5, and locking clip, drawing 35421–2 in place.

Wedge the runner blades between hub and blades to prevent them from moving. Remove the piston rod support in servomotor shown on drawing 35266 and put bushing drawing 35421–III in place. Before assembly is lifted, center the shaft in the head cover panel and block in place.

Raise the whole assembly, weighing approximately 385,000 pounds, using the special lifting arrangement shown on Baldwin Southwark's drawing 35251. Place the assembly over runner caps, drawing 35249–I and II and bolt in place, then lower in turbine pit, replacing the bolts and dowels between the inner and outer head covers.

Check the shaft for plumb and central position in the head cover barrel. Check the clearance between the tips of each runner blade at the center and the throat ring. This clearance should be the same on all blades. Install the servomotor piston using the special jacking devices, drawing 35276, then place nut 35258–2 in place using wrench 35358–II. Be sure that shoulder on piston rod is drawing up tight against piston. Check by actual measurement. After the piston is in place, install locking plate and locking clip and piston cap, shown on Baldwin Southwark's drawing 35421. Install the pipe head drawing 35421 in the lower end of the generator shaft.

Complete the assembly of the internal parts of the turbine which will include the gate servomotors, the gate links and pins, the gate ring, stairways, walkways, handrailings, and turbine piping. The oil pan and guard should be placed in the pit prior to the generator installation, since this will be awkward to handle through the passageways leading to the pit. This is not to be assembled until after the alignment check is made on the combined shafts.

SEC. 15. *Connecting turbine and generator shafts and shaft alignment.*—The turbine and generator shafts will be connected with 32 bolts 3⅝ inches in diameter, each bolt having a 1-inch hole in the center. These bolts shall be accurately measured before tightening and then tightened until they have stretched from 0.006 inch to 0.008 inch. All bolts shall be stressed an equal amount. After the shafts are coupled together and the rotor is installed, a rotation check shall be made by and at the expense of the generator contractor. This check shall be witnessed by the turbine contractor and the

Authority. The sponsor engineer's office shall be notified when this check is to be made.

The shaft shall first be checked from four plumb bob wires. The wires shall be set 90° apart and shall extend over as much of the length of the shaft as is practical. The bobs shall be suspended in heavy oil and check shall be made at four different elevations on the shaft, one near the thrust bearing, one just above the coupling, one directly below the coupling, and one near the turbine guide bearing. Plumb checks shall be at 0° and 360°. Before the shaft is rotated, two sets of tram points shall be established, one at the elevation of the generator guide bearing journal and the other at the top of the turbine guide bearing housing. These tram points shall be on the same radial lines as the plumb bob wires. Readings shall be made from these tram points to the shaft at each 90° positions, 0° to 360°, inclusive. The shaft throw-out shall not be greater than 0.012 inch in diameter and the center of this throw-out shall be set plumb within 0.005 inch between the two guide bearings. The center of the throw-out shall be set in the center of the turbine guide bearing housing within 0.002 inch.

SEC. 16. *Governors.*—The governors are furnished under a separate contract from the turbines and will be erected by TVA forces. The final adjustments will be made under the supervision of an erector from the governor contractor. The governor timing shall be set to open the wicket gates in 8 seconds and to close the wicket in 8 seconds; closing time to be exclusive of cushion at end of piston stroke. The governor shall open the runner blades in 8 seconds and close them in 12 seconds.

After the generating unit is operating, the governors shall successfully pass a load rejection test. This test shall consist of ¼, ½, ¾, and full rated load being dropped and the action of the governor observed. It is essential that the air vent valve on the turbine head cover function properly during these tests.

The overspeed device shall be set to take control at a speed not greater than 130 percent of rated speed and shall release control at 105 percent of rated speed.

SEC. 17. *Turbine test.*—An index test shall be made of the turbine to determine the shape of the discharge and the efficiency curves, to determine the capacity of the turbine, to determine the shape of the Kaplan control cam, and to calibrate the dial for the turbine integrating flowmeters.

SEC. 18. *Records.*—Accurate daily records shall be made of all important measurements and installations. Records shall contain sketches to clarify statements where necessary. One copy of all daily turbine erection records shall be furnished to the Division of Design Head Mechanical Engineer.

CONSTRUCTION SPECIFICATION NO. H14M-789—FIELD ERECTION OF HYDRAULIC FRANCIS TURBINE AND GOVERNOR, ALIGNMENT OF TURBINE AND GENERATOR SHAFTS, PRELIMINARY TESTS OF TURBINE AND GOVERNOR, CHATUGE PROJECT

(Reference drawings not included in this report)

SECTION 1. *General scope.*—This outline covers field erection of the embedded parts, concreting these parts in, the erection of internal parts of the hydraulic turbine, alignment of the turbine and generator shafts, erection of the governor, and tests of governor and turbine for the Chatuge project.

The turbines will be erected by TVA forces, and all final settings, fits, etc., shall be approved by a representative of the turbine Contractor, James Leffel & Co.

The governors will be erected by TVA forces. All final adjustments and connections will be made under the supervision of an erection engineer of the Woodward Governor Co.

The Westinghouse Electric Corp. will furnish all necessary tools, equipment, labor, and supervision, and will be responsible for erection of the generators.

The above contractors have been consulted in preparing of this outline, and it is intended to serve only as a convenient summary of standard field erec-

tion practice and does not attempt to preclude alternate methods of accomplishing the desired results.

Complete and accurate daily records of all pertinent setting, fits, and alignments shall be prepared and certified by the Authority and the erecting engineers of the contractors. Records shall contain field sketches to clarify statements where necessary. One copy of all turbine erection reports shall be furnished to the Division of Design Head Mechanical Engineer.

SEC. 2. *Reference drawings and specifications.*—Field specification for concrete to be placed around the turbine parts is covered in detail in Construction Specification No. H14C–784, except as noted herein.

The following drawings are referred to:

TVA Drawings

Concrete—Scroll Case Block Outline—Sheet 1—41N210
Concrete—Scroll Case Block Outline—Sheet 2—41N211
Mechanical—Piezometer Lines—47N400

Contractor's Drawings

Draft Tube Liner—47591
Foundation Layout—47668
Discharge Ring—47653
Stay Ring—47582
Spiral Case Details—47580
Pit Liner—47645
Pit Liner Details—47645A
Hydraulic Turbine Lubrication (Trabon)—PD708

SEC. 3. *Setting of draft tube liner.*—The draft tube liner will be shipped in one piece. Details are shown on Leffel drawing No. 47591. The liner is approximately 11 feet in diameter and when in place will extend from elevation 1788.53 to elevation 1797.17.

The draft tube liner should be placed in the recess provided, connected and anchored to the embedded anchors as shown on Leffel drawing 47668.

The liner should be carefully set to the proper elevation and center line, adjusting the leveling screws to bring it to the correct elevation and adjusting the bottom so as to align it with the top of the concrete portion of the draft tube previously placed. The transition from the steel to the previously placed concrete shall be free from any abrupt breaks or shoulders.

All foundation bolts and turnbuckles should then be tightened to hold the liner rigidly in place. When the alignment is satisfactory and the liner is adequately braced inside with steel spiders, the concrete may be placed around the liner from elevation 1787.78 up to elevation 1795.5 (through pour 11), according to special instructions for placing concrete in section 9 of this specification and construction specification No. H14C–784. The alignment and grade of the top of the draft tube liner should be checked after each pour.

SEC. 4. *Assembly of discharge ring and stay ring.*—The discharge ring is one piece cast steel as shown on drawing 47653. The stay ring is split vertically into two half-sections as shown on drawing 47582. Because there are no horizontal tie rods attached to either the stay ring or discharge ring and no jacks under the discharge ring, it is advisable to assemble these three pieces on the erection floor before placing them in position in the turbine pit. The complete assembly will weigh approximately 45,000 pounds.

Bolt the two sections of the stay ring together using the 12 fitted bolts and 8 machine bolts provided by the turbine contractor. The lower vertical machined surface of the stay ring must be round with 0.010 inch in order for the discharge ring to fit in place. If necessary, the stay ring shall be jacked into round before the discharge ring is bolted in place. The discharge ring should be located so that the horizontal clearances at opposite points are equal before the bolts are tightened.

With the three sections of the top flange of the draft tube liner bolted temporarily to the discharge ring, the complete assembly may be lowered into place on the jacks.

The stay ring shall be carefully located both horizontally and vertically, and pipe spiders shall be placed at the top and bottom flanges in order to

keep the vertical machined surfaces round. Anchor bolts and jacks shall be tightened but the joint between the discharge ring and the draft tube liner should not be made up until after the spiral case is riveted.

The center line of the unit shall be established from the embedded draft tube liner and used to locate the stay ring and other embedded parts of the turbine.

Sec. 5. *Spiral case erection.*—The spiral case will be shipped in seven sections as shown on Leffel drawing 47580. Each section shall be placed on the jacks provided and positioned to the correct location and elevation with the jacks and tie bolts.

All sections shall be bolted together 50 percent complete, with the bolts provided by the turbine contractor, before any rivets are driven. Internal bracing shall be used where required for supports and to hold the sections in their proper position, and should be left in place until after the concrete has been placed around the casing.

The lower end of the penstock is to be drilled in the field for the connection between the penstock and the spiral case. The butt strap, rivets, and fitting-up bolts will be furnished by the turbine manufacturer and the butt strap is to be used as a template for drilling the holes in the penstock. This connection may be bolted together before riveting the spiral case sections if desired.

All field-driven rivets shall be carefully inspected and all loose or defective rivets cut out and replaced.

Periodic level and concentricity checks of the stay ring shall be made during the assembly and riveting of the spiral case sections and corrections made, if necessary.

After riveting and caulking are completed a composition of cork and tar is to be placed over a portion of the top exterior surface of the spiral case as shown on drawings 41N210 and 41N211.

Sec. 6. *Connecting discharge ring and draft tube liner.*—Following completion of the spiral case and after checking the location of the stay ring, the connection between the discharge ring and the stay ring may be made. The rivet holes for connecting the draft tube liner to the top flange are to be field-drilled. Using the top flange as a template drill the holes in the draft tube liner and cut the top of the liner to the correct elevation in accordance with the details on drawing 47591. After drilling, remove the flange so that all chips and burrs may be removed, replace flange and rivet it to the draft tube liner.

Care should be exercised in placing the weld between the liner and the top flange in order to avoid warping or undercutting. Welding should present a smooth surface in this area in order to prevent cavitation.

Sec. 7. *Placing pit liner.*—The pit liner is split vertically into two sections as shown on drawings 47645 and 47645A. Bolt the sections together and connect the assembled pit liner to the stay ring. Center the liner about a wire, centered in the stay ring. Particular attention should be paid to the alignment of the servomotor bases. These should be correct. Check the completed assembly for position to make sure the servomotor mechanism can be installed correctly.

Sec. 8. *Howell-Bunger valve connection.*—The flange for connecting the Howell-Bunger valve to the spiral case is to be field-drilled to match the bolt holes in the valve. The 64 holes are to be drilled to 2 inches in diameter; the anchor bolts are 1¾ inches in diameter.

After assembly of the spiral case is completed the nozzle flange shall be checked for roundness and securely braced.

A template shall be made of plywood of a minimum thickness of ¾ inch as follows:

a. Check valve flange for roundness and make necessary corrections.
b. Clamp template securely to valve flange.
c. Using a ⅛-inch-thick sleeve and a 1¾-inch drill, drill template to match valve flange.
d. Mark template so that it can be oriented properly when drilling nozzle flange.

The nozzle flange is to be drilled as follows:
a. Check the nozzle flange for roundness and make necessary corrections.
b. Clamp template securely to the nozzle flange.

c. Drill lead holes completely through flange using a sleeve with 1¾-inch o.d. and i.d. same as lead drill.

d. Remove template and drill holes to 2 inches in diameter.

The template may be used as a spacer for holding the anchor bolts in the proper location when concreting the spiral case.

SEC. 9. *Placing concrete around embedded parts.*—The various concrete pours and the method for making them are outlined on TVA drawing No. 41N210 and construction specification No. H14C-784. Plastic concrete around the assembly should be held to 1 foot vertically in order to avoid excessive side thrust. Vibrators in motion shall not be allowed to come in contact with any tie rods, bolts, jack, wedges, or any metal part of the turbine.

After a *minimum* of 7 days from the time the concrete was placed in pour 14 under the stay ring the remaining void may be filled with grout. For this purpose, holes have been provided in the stay ring. In addition, small weep holes are also provided to ensure that no water or air will be entrapped and thus cause voids after grouting. The grout shall be placed through the holes by means of individual pipe risers, or, if necessary, these may be made from wood. The pipes or boxes should be so arranged that continuous rodding of the grout is possible, allowing all water and wet grout to escape through the weep holes and to ensure that the whole area under the metal is well-filled with grout which is as dry and dense as possible. The lower the water-cement ratio, the lower the amount of shrinking will be. Therefore, it is highly desirable that all water possible be worked out of the grout. After the grout has set but before it becomes hard, remove the risers and dig the grout out to a depth of one-half inch below the top surface of the metal so that metal inserts may be placed in the holes, welded in, and ground flush.

During the placing of the concrete around and under the embedded parts, water should be sprayed on the inside of the metal parts to keep the metal from expanding due to the heat generated by the setting of the concrete. Position checks should be made following each pour.

SEC. 10. *Installation of piezometer lines.*—Piezometer taps are provided in the spiral case for operating the turbine flowmeter, in the Howell-Bunger valve nozzle for calibrating the flow through the valve, and at the entrance to the spiral case for obtaining the net head.

The spiral case will be shipped with ¾-inch brass pipe plugs screwed into the piezometer openings. The outside plugs are to be removed when the piping is connected. The inside plugs are to be ground smooth with the surface of the spiral case and the spiral case cleaned and ground smooth for a radius of 6 inches around the plug. Drill a ⅜-inch hole in the center of the plug and normal to the inside surface of the spiral case and remove the sharp corner. The corner may be removed by turning a large drill bit or pipe reamer several times in the hole by hand.

Piezometer line piping is to be installed in accordance with drawing 47N400. Piping inside the junction box is not to be installed until after the index test has been made on the unit. Plugged tees are to be used in making the connections in the junction box so that taps will be available for possible future tests on the unit.

All lines shall be flushed with water before filling the spiral case in order to remove any foreign matter which might be present.

SEC. 11. *Installation of internal parts.*—The bottom ring, crown plate, and at least eight wicket gates (in pairs) shall be placed in their proper locations and centered about a plumb wire located at the center of the stay ring. The crown plate should be kept level while lowering it over the wicket gate stems in order to keep the stems from binding. The crown plate shall be checked for level and bolted temporarily in place using metal shims for leveling and keeping the crown plate centered about the plumb wire. The clearance at the heel and toe of each gate and at the seal between adjacent gates shall be checked, and the bottom ring repositioned to make the heel and toe clearances equal and the clearance at the gate seals zero at both top and bottom of the gates. If necessary, in order to make the gates fit properly, the crown plate may be repositioned. When both crown plate and bottom ring are correctly located the crown plate shall be temporarily doweled to the stay ring and the bottom ring permanently doweled and bolted to the discharge ring. It will be

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necessary to remove the crown plate and place the remaining eight wicket gates in place before placing the runner and shaft in position.

In connecting the runner to the shaft care should be taken to obtain approximately equal tension in all bolts. After the studs have been tightened in the runner and the drive pins inserted in shaft, the shaft may be lowered in place on the runner. The threads and face of the nuts should be lubricated (preferably with a mixture of oil and graphite) before tightening. A torque of about 19,000 inch-pounds applied to the nut should stress the bolts sufficiently. This amounts to a 400-pound pull on the end of a 48-inch wrench. When all nuts are tight, the nuts and studs shall be locked by tack welds.

The runner and shaft may now be lowered into position, and the crown plate doweled and bolted in place. Following this, the remainder of the internal parts with the exception of the guide bearing may be installed. The two sections of the guide bearing should be placed in the turbine pit but shall not be installed in the crown plate until after the rotation check has been made.

Before the coupling between the generator and turbine shafts is made up the turbine shaft shall be centered, plumbed, and blocked in place with pipe jacks.

SEC. 12. *Combined turbine and generator shaft alignment.*—The turbine and generator shafts will be connected by TVA under the generator contractor's supervision, with fourteen 3-inch bolts. The following procedure shall be followed in making up the coupling:

a. Pull turbine and generator shafts together with four volts spaced approximately 90° apart. Tighten these bolts sufficiently to hold the two shafts together tightly.

b. Insert remaining bolts and tighten to approximately same torque as first four bolts. (The face and threads of one nut on each bolt should be lubricated with an oil and graphite mixture.)

c. Loosen one bolt, carefully measure its length with a micrometer, and retighten until it has stretched from 0.005 to 0.007 inch.

d. Repeat this procedure for all 14 bolts alternately tightening bolts on opposite sides of the shaft.

When the coupling is made and the shaft is hanging free with the weight of all the rotating parts of the combined turbine and generator resting on the thrust bearing, a rotation and plumb check of the combined shafts shall be made. Four plumb bobs in oil, suspended from near the generator bridge, shall be used to check the shaft for plumb. The bobs shall be set 90° apart and the piano wires, which support the bobs, shall extend over as much of the length of shafts as possible. The shaft shall be checked for plumb at four elevations: one near the thrust bearing, one on the generator shaft coupling flange, one on the turbine shaft coupling flange, and one on or near the turbine guide bearing journal. A plumb check shall be made at the 0° and 360° position.

The combined shaft shall be rotated and checked from the upper and lower points at each 90° position, 0° through 360°, and the diameter of the wobble or throw-out, as determined by this check, shall not exceed at the turbine guide bearing the amount determined by the formula $\frac{L}{D} \times 0.0015$ inch where D = diameter of the thrust bearing runner plate and L = the vertical distance between the lower face of the thrust bearing runner plate and the center of the turbine guide bearing. The center of the throw-out circle, as determined by the rotation check, shall be set plumb within 0.005 inch, and the center of the throw-out circle shall be set central in the turbine guide bearing housing within 0.002 inch.

The rotation check shall be made by and at the expense of the generator manufacturer. All readings and settings are to be witnessed by TVA. The Division of Design shall be notified when the alignment check is to be made so that a design engineer may witness the check.

SEC. 13. *Automatic greasing system.*—The turbine guide bearing and the wicket gate mechanism are to be lubricated with an automatic pressure greasing system provided by the turbine contractor. The greasing system consists of one pump, two control boxes, two solenoid valves, and the necessary pipe and feeders. One control box contains the long interval timer which con-

trols the grease supplied to the wicket gate mechanism, and the other control box contains the short interval timer which controls the grease supplied to the turbine guide bearing.

The grease piping in the turbine pit shall be made in accordance with Trabon Engineering Corp. drawing PD–708. Actual location of the piping and feeders shall be determined in the field.

The long interval timer operates to close a pneumatic relay (H1) which is adjustable from zero to 3 minutes. The interval of this timer can be set for either ½ hour, 1 hour, 2 hours, 3 hours, 4 hours, 6 hours, or 12 hours. Therefore, the long interval timer can be set to turn the lubrication pump on at any time interval mentioned above and the pneumatic relay adjusted to hold it on for any length of time up to a maximum of 3 minutes.

The long interval timer shall be adjusted initially for an interval of 6 hours and the pneumatic relay adjusted so that the pump will remain on long enough to operate the microswitch on master feeder "A" through one complete cycle. One cycle of master feeder "A" will require a pneumatic relay time of approximately 15 seconds. If after a few weeks' operation the wicket gate mechanism appears to be getting an incorrect amount of grease either the interval timer, the pneumatic relay, or both may be readjusted to increase or decrease the amount of grease as desired.

The short interval timer, which controls the amount of grease to the turbine guide bearing, can be adjusted to hold the pump on for any length of time from 15 seconds to 60 minutes. This timer shall be initially adjusted to start the pump at 15-minute intervals and hold the pump on for a time of 15 seconds. This time should operate master feeder "D" through one complete cycle.

Prior to operating the unit all bearings shall be filled with grease and the automatic greasing equipment operated to see that it functions properly.

During the initial operation of the unit the guide bearing temperature shall be carefully observed and if the temperature shows a tendency to continue rising or shows too great a rise the greasing time interval shall be decreased sufficiently to keep the temperature within safe limits.

Sec. 14. *Governor.*—The governor is furnished by Woodward Governor Co. under a separate contract from the turbine. The governor will be erected by TVA forces. The final adjustments and connections shall be made under the supervision of an erecting engineer from the governor manufacturer.

The wicket gate timing at this plant is rather critical due to the long penstock and high water velocities. A gate timing which is too fast could cause dangerously high water-hammer pressures, or one that is too slow would cause an excessive speed rise and poor regulation. The governor shall be set to open or close the wicket gates in 8 seconds, exclusive of the additional time required for cushioning. This can be accomplished by adjusting the stops on the valve so that the time required for the gates to travel from 75 percent to 25 percent open during a full gate closure (25 to 75 percent for gates opening) is 4 seconds.

The overspeed device shall be set to take control at a speed not greater than 130 percent of rated speed (234 rpm) and to release control at a speed not greater than 105 percent of rated speed (189 rpm).

It is most important that the governor oil be free from all scale, grit, waste, lint, or other foreign matter. Before the governing system is filled with oil, all piping shall be thoroughly cleaned and flushed by circulating oil. The governor sump tank shall be inspected and cleaned. The pressure tank shall be inspected and cleaned. Care should be taken during the erection of all oil piping to make sure that no foreign matter is left in them. During the time that oil is circulating through the pipes they shall be lightly tapped with a small hammer. This will help to loosen and remove any scale or welding beads which might be sticking to the inside of the pipes.

Sec. 15. *Turbine and governor test.*—After the machine is in operation, the governor shall successfully pass load rejection tests. These tests shall consist of one-fourth, one-half, three-fourths, and full load being dropped and the action of the governor recorded and observed. An index test shall be made of the turbine to determine the shape of the discharge and efficiency curves, to determine the capacity of the turbines, and to determine the calibration of the turbine flowmeter.

The above tests shall be made by TVA under the direction of the Division of Design. The manufacturer will be notified in advance of these tests so that he may have a representative present if he so desires.

HYDRO GENERATING EQUIPMENT SELECTED DATA

Table 27, following, comprises this entire section. For each of the 23 projects in which TVA installed generating units it gives the type of turbine, the unit numbers listed in the sequence of their installation, the nameplate rating of each unit in kilowatts, the names of the contractors who furnished the turbines and generators, the contract number, the dates of the contract awards, the dates of commercial operation of the first and last units installed in each project, and the contract prices including the prices per kilowatt. Totals of the turbines, generators, capacities, and contract prices are given at the end of the table.

Brief statistical data for each project showing authorization, construction, and unit operation dates, and cost, appear in the introductory remarks to each project section in chapter 2.

TABLE 27.—*Installation, contract, and related data on hydro generating units installed by TVA*

Project	Item	Type [1] of turbine	Unit No. (in sequence of installation)	Kw per unit (name plate)	Contractor	Contract No.	Dates: Award	Dates: Commercial operation: First unit	Dates: Commercial operation: Last unit	Contract [2] price	Price per kw.
Kentucky	Turbines	K	3-2-1-4-5		Allis Chalmers	65059	8-13-41			$3,372,845	$21.08
	Generators		3-2-1-4-5	32,000	General Electric	65058	8-13-41	9-14-44	1-16-48	2,717,273	16.98
Pickwick Landing	Turbines	K	2-1		Allis Chalmers	5312	8-17-36			1,000,163	13.89
	Generators		2-1	36,000	Westinghouse	10384	8-17-36	6-29-38		932,287	12.95
	Turbine	K	4		Allis Chalmers	52039	5- 3-40			616,900	17.14
	Generator		4	36,000	Westinghouse	52037	5- 3-40			536,405	14.90
	Turbine	K	3		Allis Chalmers	55011	8-13-40			605,200	16.81
	Generator		3	36,000	Westinghouse	55006	8- 9-40			520,000	14.44
	Turbines	K	5-6		Allis Chalmers	7327A	8-16-49			2,200,000	30.56
	Generators		5-6	36,000	Westinghouse	7215A	7-27-49		12-31-52	2,228,483	30.95
Wilson [3]	Turbines	F	12-11		Allis Chalmers	52105	5-10-40			367,613	7.29
	Generators		12-11	25,200	do	52104	5-10-40	3-25-42		704,600	13.98
	Turbines	F	10-9		do	55013	8-13-40			364,333	7.23
	Generators		10-9	25,200	do	55012	8-13-40			713,627	14.16
	Turbines	F	16-15		do	65060	8-13-41			425,129	8.44
	Generators		16-15	25,200	do	65152	8-26-41			725,015	14.39
	Turbines	F	13-14-17-18		do	96612	4-24-47			1,233,846	12.24
	Generators		13-14-17-18	25,200	do	96611	4-24-47		3-20-50	2,487,705	24.68
Wheeler	Turbine	FB	1		Baldwin	830	10-22-34			[4] 362,160	11.18
	Generator		1	32,400	General Electric	907	1-17-35	11-9-36		424,661	13.11
	Turbine	FB	2		Baldwin	1658	11-18-35			[4] 332,862	10.27
	Generator		2	32,400	General Electric	1657	11-18-35			409,425	12.64
	Turbines	FB	3-4		Baldwin	42854	8-16-39			784,992	12.11
	Generators		3-4	32,400	General Electric	42855	8-16-39			1,009,987	15.59
	Turbines	FB	5-6		Baldwin	92966	7- 8-46			[4] 1,318,707	20.35
	Generators		5-6	32,400	General Electric	92990	7-10-46			1,414,459	21.83
	Turbines	FB	7-8		Baldwin	98099	6-24-47			[4] 1,347,815	20.80
	Generators		7-8	32,400	General Electric	98115	6-24-47		3-4-50	1,530,300	23.62
Guntersville	Turbines	K	1-2		S. Morgan Smith	18682	8- -37			1,018,729	20.96
	Generators		1-2	24,300	General Electric	21983	11- -37	8-1-39		934,102	19.22
	Turbine	K	3		S. Morgan Smith	30354	7- -38			485,599	19.98
	Generator		3	24,300	General Electric	30353	7- -38			452,925	18.64
	Turbine	K	4		S. Morgan Smith	5163A	5-12-49			[4] 775,735	31.92
	Generator		4	24,300	General Electric	5159A	5-12-49		3-24-52	902,481	37.14
Hales Bar [3]	Turbines	K	15-16		S. Morgan Smith	7217A	7-27-49			[4] 1,498,074	30.82
	Generators		15-16	24,300	General Electric	7325A	8-15-49	7-11-52	12-23-52	2,049,508	42.17

See footnotes at end of table.

TABLE 27.—*Installation, contract, and related data on hydro generating units installed by TVA*—Continued

Project	Item	Type [1] of turbine	Unit No. (in sequence of installation)	Kw per unit (name plate)	Contractor	Contract No.	Dates: Award	Dates: Commercial operation: First unit	Dates: Commercial operation: Last unit	Contract [2] price	Price per kw.
Chickamauga	Turbines	K	3-2		Baldwin	18683	8-18-37			1,048,167	19.41
	Generators		3-2-1	27,000	Allis Chalmers	31469	8- 2-38	3-4-40		1,449,893	17.90
	Turbine	K	1		Baldwin	30402	7-11-38			491,979	18.22
	Turbine	K	4		do	5162A	5-12-49			[4] 881,205	32.64
	Generator		4	27,000	Allis Chalmers	5158A	5-12-49		3-7-52	971,740	35.99
Watts Bar	Turbines	K	3-2-1		Baldwin	51328	4- 8-40			1,395,210	15.50
	Generators		3-2-1	30,000	Westinghouse	51327	4- 8-40	2-11-42		1,404,400	15.60
	Turbines	K	5-4		Baldwin	65071	8-15-41			1,095,076	18.25
	Generators		5-4	30,000	Westinghouse	65072	8-15-41		4-24-44	958,490	15.97
Fort Loudoun	Turbines	K	2-1		Baldwin	55170	5- 1-41			[4] 990,873	15.48
	Generators		2-1	32,000	Allis Chalmers	55178	5- 2-41	11-9-43		993,821	14.59
	Turbines	K	3-4		Baldwin	92965	7- 8-46			[4] 1,313,451	20.52
	Generators		3-4	32,000	Allis Chalmers	92955	7- 5-46		1-27-49	1,291,062	20.17
Apalachia	Turbines	F	2-1		Baldwin	65185	8-30-41			651,707	8.69
	Generators		2-1	37,500	Westinghouse	65183	8-29-41	9-22-43	11-17-43	609,475	8.13
Hiwassee	Turbine	F	1		Newport News	32656	9-20-38			[4] 300,632	5.22
	Generator		1	57,600	Westinghouse	34293	11-10-38	5-21-40		531,300	9.22
	Turbine	PF [5]	2		Allis Chalmers	C-53-18861	10-14-52			[4] 1,271,745	21.37
	Generator		2	59,500	do	8329A	10-13-52		5-24-56	1,303,055	21.90
Chatuge	Turbine	F	1		Jas. T. Leffel	C-53-16692	8-14-52			[4] 237,361	23.74
	Generator		1	10,000	Westinghouse	8326A	9-22-52	12-9-54	12-9-54	[3] 350,062	35.01
Nottely	Turbine	F	1		Jas. T. Leffel	C-53-20754	12- 3-52			[4] 302,349	20.16
	Generator		1	15,000	Westinghouse	8344A	12-19-52	1-10-56	1-10-56	430,998	28.73
Ocoee No. 3	Turbine	F	1		S. Morgan Smith	65186	8-30-41			[4] 208,764	7.73
	Generator		1	27,000	Westinghouse	65182	8-29-41	4-30-43	4-30-43	253,794	9.40
Norris	Turbines	F	2-1		Newport News	831	10-22-34			[4] 495,440	4.92
	Generators		2-1	50,400	Westinghouse	906	1-17-35	7-28-36	9-30-36	880,120	8.73
Fontana	Turbines	F	1-2		Allis Chalmers	68100	3-20-42			1,011,611	7.49
	Generators		1-2	67,500	Westinghouse	69579	2- 7-42	1-20-45		1,135,706	8.41
	Turbine	F	3		Allis Chalmers	C-51-6194	7-10-50			702,800	10.41
	Generator		3	67,500	Westinghouse	8087A	7-27-50		2- 4-54	1,163,194	17.23
Douglas	Turbine	F	3		S. Morgan Smith	55017	8-23-40			[4] 282,086	9.40
	Generator		3	30,000	General Electric	55015	8-22-40	3-21-43		412,025	13.73
	Turbine	F	1		S. Morgan Smith	69798	2-19-42			[4] 335,036	11.17
	Generator		1	30,000	General Electric	69580	2- 7-42			412,491	13.75
	Turbine	F	2		S. Morgan Smith	93394	9-11-46			[4] 415,940	16.00
	Generator		2	26,000	General Electric	93483	9-23-46			463,501	17.83
	Turbine	F	4		S. Morgan Smith	C-52-11719	9-12-51			[4] 578 237	22.24
	Generator		4	26,000	General Electric	8205A	8-20-51		8- 3-54	748,420	28.79

Cherokee	Turbines	F	1-3		S. Morgan Smith	55017	8-23-40			[4] 571,590	9.53
	Generators		1-3	30,000	General Electric	55015	8-22-40	4-16-42		820,609	13.68
	Turbine	F	2		S. Morgan Smith	C-51-9014	10-4-50			[4] 437,680	14.59
	Generator		2	30,000	General Electric	8118A	11-7-50			[3] 762,319	25.41
	Turbine	F	4		S. Morgan Smith	C-51-12354	1-19-51			[4] 480,148	16.00
	Generator		4	30,000	General Electric	8130A	1-18-51		10-7-53	762,038	25.40
South Holston	Turbine	F	1		S. Morgan Smith	2217A	5-12-48			[4] 421,759	12.05
	Generator		1	35,000	Westinghouse	2475A	6-21-48	2-13-51	2-13-51	711,485	20.33
Watauga	Turbines	F	2-1		Newport News	94534	11-4-46			[4] 478,418	9.57
	Generators		2-1	25,000	Westinghouse	94574	11-7-46	8-30-49	9-29-49	863,579	17.27
Wilbur [3]	Turbine	FB	4		Jas. T. Leffel	2627A	6-28-48			169,811	24.25
	Generator		4	7,000	Elliott Co.	2975A	8-20-48	7-19-50	7-19-50	198,640	28.38
Boone	Turbines	F	3-2-1		Newport News	C-51-8031	9-5-50			[4] 1,103,395	14.71
	Generators		3-2-1	25,000	Westinghouse	8108A	10-19-50	3-16-53	9-3-53	2,351,304	31.35
Fort Patrick Henry	Turbines	K	2-1		Newport News	C-51-26623	5-11-51			780,300	21.68
	Generators		2-1	18,000	Westinghouse	8170A	6-5-51	12-5-53	2-22-54	1,084,012	30.11
Totals: 77 Turbines										36,563,473	15.23
77 Generators—2,401,400 kw. nameplate capacity										44,010,776	18.33

[1] K = Kaplan; F = Francis; FB = Fixed-blade propeller; PF = Pump-turbine, Francis.

[2] Contract prices are amounts shown in contract documents or where available they are the actual costs as shown in the final reports reflecting minor contract adjustments after award; prices for turbines include governors in all cases but do not include erection; generator prices include erection in place.

[3] Does not include units installed before acquisition of project by TVA.

[4] Governors are included but were actually purchased under separate contract with Woodward Governor Co.

[5] As a pump the rating of unit 2 is 3,900 cubic feet per second at a total dynamic head of 205 feet.

Appendix B

AUXILIARY EQUIPMENT SPECIFICATIONS

Appendix B includes typical auxiliary mechanical equipment specifications. The general clauses of invitation to bid documents are omitted as these typical clauses of this nature were presented in their entirety in appendix A, Fort Patrick Henry Turbine and Governor Specifications.

The specifications contained in this appendix are: *Page*

SPECIFICATION NO. 1673—GASOLINE ENGINE GENERATOR UNIT, FORT LOUDOUN PROJECT

(Reference drawings not included in this report)

GENERAL PROVISIONS

SECTION 1. *The requirement.*—The work covered by this specification comprises the furnishing and delivering of one 480-volt, 300-kva, 0.8 power factor, 60-cycle, 3-phase, 1200-rpm, gasoline engine, electric-generator unit, with accessories required for satisfactory operation, complete and ready for installation in the Fort Loudoun powerhouse.

The equipment to be furnished shall comprise a complete unit. In accordance with this specification and the Authority's drawing No. 45B714RO and in accordance with the specifications and drawings submitted by the contractor with his bid.

The contractor will not be required to install the equipment furnished by him nor to furnish any external conduit nor wiring, cooling water supply nor drain, nor gasoline storage tank.

SEC. 2. *General description.*—The gasoline-engine electric-generator unit will be used for emergency standby service. It will be located indoors, in the powerhouse, at an altitude of approximately 768 feet above mean sea level. The unit shall consist of a gasoline engine direct-connected to an alternating-current generator with a direct-connected exciter, all mounted on a rigid

common base. The cooling water supply will have a maximum temperature of approximately 85° F.

The gasoline engine shall be of the horizontal-shaft, multi-cylinder, 4-cycle, water-cooled type. The engine shall be equipped with an enclosed flywheel; lubricating oil pump; full pressure lubricating system; cooling water circulating pump if required; starting motor or motors with starting switch and storage batteries; suitable battery-charging generator with regulator and external charger with selector switches and suitable housing; throttle governor and mechanical overspeed device; ignition system with switch; carburetors with inlet air cleaners and backfire arresters; Underwriter's fuel pumping system; water-cooled exhaust manifold; lubricating oil filter and cooler; enclosed flexible coupling between engine shaft and generator shaft; exhaust muffler, water-cooled exhaust pipe; cooling water thermometer; cooling water pressure gauge; tachometer; oil level gauge; manual regulation of the cooling water supply; and all gauges, instruments, and accessories required for the convenient operation and maintenance of the engine.

The electric generator shall be a 480-volt, 300-kva, 0.8 power factor, 1200-rpm alternating-current generator with direct-connected exciter. The contractor shall furnish a control switchboard with rheostat, electric instruments, voltage regulator, and control and protective equipment, mounted and wired as shown on the accompanying Authority's drawing.

The complete unit shall be not more than 16 feet long, not more than 5 feet wide, and not more than 7 feet high, overall dimensions.

SEC. 3. *The engineer.*—Work under this specification shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the Engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specification.

SEC. 4. *Drawings to be furnished by the contractor.*—The contractor shall furnish seven copies of assembly and detail drawings and cuts in such detail as necessary for installation, operation, and maintenance of the equipment and for demonstrating that it complies with the requirements of the specification. All drawings shall be clearly identified by serial numbers and descriptive titles, indicating their application to the contract, and furnished in such sequence that the engineer has all information necessary for checking. All prints shall be on paper except that one print of the principal assembly and cross-sectional drawings shall be on cloth for record purposes.

The drawings and information to be submitted by the contractor shall include:

a. Detail and arrangement drawings of the equipment in elevation and plan, including motor outline sheets, giving all important dimensions, location, and size of connections, conduits, etc.

b. Complete wiring diagrams of all electrical equipment.

c. Cross-sectional drawings of the complete equipment showing all compressor parts for future spare parts replacement identification. These may be included in the instruction sets below.

d. Six complete sets of installation and operating instruction, each neatly bound in a folder.

Any drawings that may require approval by the Authority will be promptly returned to the contractor with approval or necessary corrections and revisions. In the case of drawings returned to the contractor without approval, they shall be corrected and resubmitted as before. No cloth prints shall be submitted prior to approval by the Authority.

Upon completion of work, the contractor shall furnish the Authority one vandyke negative and two paper prints of all drawings previously submitted and three copies of all bulletins for record purposes. The contractor shall furnish certified data sheets in quintuplicate of all factory tests. The results of the factory tests shall be certified by a responsible officer of the contractor and shall be subject to approval of the engineer before delivery of the equipment, but this approval shall not relieve the contractor of any obligation to meet all the requirements of this specification.

Sec. 5. *Materials and workmanship.*—Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

Where the characteristics of any material are not explicitly specified, approved material meeting the requirements of the appropriate specifications of the American Society for Testing Materials or other recognized standard shall be employed.

Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish, when not definitely specied, shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

Sec. 6. *Equipment.*—All equipment shall be new and of current model and latest design, and shall be of standard, commercial, first-grade quality as to material, workmanship, and design, in accordance with the best engineering practice, and shall be such as has been proved to be suitable for the intended purpose, except that in minor details there will be permitted departures from previous designs, provided such departures are definite improvements over earlier designs.

Unless otherwise specified herein, all electrical equipment shall conform to the latest published standards of AIEE and NEMA as to all features of material, workmanship, design, and tests, where applicable.

Sec. 7. *Access to work.*—The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract and shall have full facilities for unrestricted inspection of such materials or equipment.

Sec. 8. *Shop inspection and material orders.*—No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the Engineer authorizes inspection to be made elsewhere.

The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

Sec. 9. *Marking.*—All parts or units of assembly shall be adequately marked. Marks shall be in accordance with drawings or order lists, shall be clearly legible and so placed as to be readily visible when the part is being erected in the field. All pieces weighing more than 1 ton shall have the approximate weight marked thereon.

Connecting parts, assembled in the shop, shall, before dismantling for shipment, be matchmarked to facilitate erection in the field. The location of the matchmarks shall be clearly indicated.

Sec. 10. *Preparation for shipment.*—The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

All finished surfaces shall be coated with white lead and tallow applied hot, except that cut threads shall be coated with heavy oil.

GASOLINE ENGINE

Sec. 11. *General.*—The engine shall be a standard product and of a design which has been proved reliable and satisfactory in use. The engine shall be capable of developing continuously at least 425 brake horsepower with a mean effective cylinder pressure of not more than 105 pounds per square inch and at a mean piston speed of not more than 1,800 feet per minute. The engine

shall operate satisfactorily and comply with this specification when using gasoline fuel conforming to Federal Specifications No. VV-G-101-a, and having an octane rating of 65-70.

The exhaust manifold and instrument panel shall be on the right side of the engine when facing the generator end of the unit.

The exhaust manifold shall be fully water-jacketed.

The engine flywheel shall be of steel and shall be fully enclosed.

The crankshaft shall be of one piece of forged heat-treated steel. It shall be satisfactorily balanced, and its crankpin and journal bearings shall be accurately and uniformly ground to size and polished.

The crankcase shall be of ample strength and shall have handholes of ample size on both sides of the upper part of the case for inspection of the interior and for replacement of bearings.

The camshaft shall be of forged heat-treated steel with the cams integral with the shaft. The cams and bearings shall be ground and polished.

The pistons shall be of an approved metal.

SEC. 12. *Bearings.*—All bearings shall be of ample size and number for the use intended and shall be of approved bronze, babbitt, or anti-friction type. They shall be readily removable for replacement or repair.

SEC. 13. *Lubricating system.*—All moving parts, bearings, gears, and chain drives shall be satisfactorily lubricated automatically. Lubricating oil shall be supplied under pressure to the main bearings, to the connecting rod bearings, to the camshaft and timing gears, and to the valve-operating mechanism. The oil pump shall be gear or silent-chain driven and shall be self-priming. A suitable oil filter and a suitable water-cooled oil cooler shall be conveniently mounted on the engine with all necessary piping and designed to cool and to filter all lubricating oil each time it passes through the system. An oil pressure gauge and an oil level indicator shall be furnished and conveniently mounted on the engine. Oil drain shall be piped to outside of base.

SEC. 14. *Cooling water system.*—The engine will be located on floor elevation 768. The cooling water will be supplied from the dam forebay with maximum pressure at floor line of 20 psi and minimum pressure of 6 psi. If this is insufficient head for the cooling supply, the contractor shall supply a cooling water pump conveniently mounted on the engine. The contractor shall supply a cooling water thermometer on the discharge side of the engine, a pressure gauge, a sight flow indicator, necessary valves, and a pressure switch with contacts to stop the engine if the cooling water pressure fails and also to sound an alarm bell, which shall be furnished by the contractor. Contacts for the alarm shall be interlocked with the engine ignition to render the alarm inoperative when ignition is turned off.

The pressure switch shall be of such design and shall be so located that the starting of the cooling water pump shall not reduce the pressure in the cooling water line sufficiently to cause the switch to shut off the ignition.

SEC. 15. *The fuel pumping system.*—The fuel pumping system shall be furnished by the contractor. It shall conform to the requirements of the Board of Fire Underwriters and shall consist of diaphragm-type engine-driven gasoline pumps and hand-operated gasoline pump, together with the required strainers, valves, gauges, and other accessories. The fuel system shall be designed to pump fuel from a gasoline storage tank provided by the Authority, and the vertical lift to the engine room floor will not exceed 8 feet, 3 inches. There shall be no fuel suspended in receptacle in the engine room.

SEC. 16. *Ignition system.*—The ignition system shall be of the dual type operated from the starting motor storage battery. An approved-type ignition switch shall be furnished and mounted on the engine panel.

SEC. 17. *Carburetors.*—The engine shall be equipped with at least two suitable carburetors, each with a suitable air cleaner and backfire arrester and with flood cups or drip pans under each carburetor.

SEC. 18. *Governor.*—The engine shall be equipped with a throttle governor mounted on the engine which will maintain satisfactory speed regulation of the unit when it is operating under a variable load. It shall be of a non-

hunting, precision type, capable of maintaining the speed of the engine within 8 percent of rated speed during part load changes or within 20 percent when full load is suddenly thrown on the engine coming back to rated speed and in not more than 8 seconds. The engine shall be equipped with adjustable mechanical overspeed device which will shut down the engine in case its speed should exceed 1,500 rpm.

All gears, chain drives, the valve-operating mechanism, and other similar moving parts shall be totally enclosed in oiltight cases. All accessories on the engine shall be mounted in a neat and secure manner.

SEC. 19. *The starting motor.*—The starting motor, or motors, shall be operated from 12-volt storage batteries to be supplied with the engine. Starting shall be accomplished by means of magnetic contactor and push button interlocked with the engine spark control lever to prevent starting unless the engine spark control is in full retard position.

SEC. 20. *The flexible coupling.*—The flexible coupling connecting the engine and generator shafts shall be of an approved type and shall be totally enclosed with a sturdy housing.

SEC. 21. *The exhaust muffler.*—The exhaust muffler shall be of ample size and equal to a Burgess snubber.

SEC. 21-A. *Water-cooled exhaust.*—A water-cooled exhaust shall be provided which shall be attached to the engine manifold at the generator end of the unit which shall be not more than 12 feet in length.

SEC. 22. *Tools.*—The contractor shall furnish any special tools, hand-starting crank, or wrenches necessary for the convenient installation and maintenance of the equipment to be furnished.

SEC. 23. *Base.*—The common base for the engine and generator shall be of rigid cast-iron, cast-steel, or welded structural construction and shall be provided with a drip ledge. It shall be ribbed or braced longitudinally and transversely and shall have large grout holes.

SEC. 24. *Battery-charging generator.*—The engine shall be equipped with a 12-volt, approximately 225-watt generator with voltage regulator and magneto cutout, mounted on the engine.

SEC. 25. *Storage batteries.*—There shall be furnished two duplicate 12-volt, 300-ampere-hour storage batteries each consisting of four 6-volt units, with necessary jumper connections. Each 6-volt unit shall have a rating of 150 ampere-hours at 20-hour rate.

SEC. 26. *Storage battery cabinet and trickle charger.*—There shall be furnished a welded steel cabinet with angle frame, hardwood shelves, and sheet lead trays of sufficient size to accommodate the two 12-volt batteries. The cabinet shall be enclosed and provided with suitable louvers for ventilation and with double hinged doors on one side. The inside of the cabinet shall be covered with acid-resisting paint and the outside finished in dull black.

A battery discharge selector switch, type A, double pole, double throw, with a rating of 200 amperes at 250 volts, and with copper bar connectors to provide 400-ampere capacity when used as a single-pole, double-throw switch shall be furnished fully enclosed in a sheet-steel safety-type box suitable for wall mounting.

A battery trickle charging selector switch, 30-ampere capacity at 250 volts, of the enclosed safety type, shall be furnished, suitable for wall mounting.

A battery trickle charger shall be provided for operation on 110- to 115-volt, 60-cycle, a.c. supply for charging the storage batteries at the rate of 6 to 12 amperes, as desired. Charging unit shall be constructed with an insulated transformer and shall be equal to the G. E. tungar type. An ON and OFF switch shall be installed on the charging unit for the control of the a.c. supply and a switch shall be furnished for the a.c. supply marked HIGH and LOW to provide dual charging rate of 6 amperes in the low position and 12

amperes in the high position. An ammeter 0- to 20-ampere d.c. and a voltmeter 0- to 20-volt d.c. range shall be installed on the charging unit.

SEC. 27. *Engine instrument panel.*—The engine instrument panel shall contain spark and throttle controls, main oil line pressure gage; pressure gage for lubricating oil prior to entering oil filter and oil pressure after leaving oil filter; ignition switch; starting motor push button; speed indicator; and a 12-volt 3- to 4-candlepower panel lamp. The above instruments shall be substantially mounted on the instrument panel. Suitable brackets shall be furnished for the mounting of the panel to the engine to eliminate all possible vibration.

GENERATOR

SEC. 28. *Type and rating.*—The generator and exciter shall be standard products of an approved manufacturer. The generator shall be of the horizontal shaft, direct-connected type with squirrel cage, amortisseur winding, and with direct-connect exciter. The nominal rating of the generator shall be as follows:

Continuous capacity—300 kva
Power factor—0.8 lagging
Frequency—60 cycles
Number of phases—3
Voltage—480
Speed—1,200 rpm

In addition to the above, the electrical characteristics of the generator, exciter, and voltage regulator shall be such as will ensure the satisfactory starting of a 125-horsepower, normal torque, low-starting-current motor direct-connected to a centrifugal-type sump pump and during starting shall maintain not less than 65 percent of rated voltage. The motor will have a locked-rotor current of 800 amperes at 0.3 power factor with 440 volts applied.

The generator, exciter, and all other electrical equipment shall conform to the applicable standards, codes, and rules of the AIEE and NEMA as to material, construction, operation, and tests. The temperature rise of generator and exciter shall conform to the standards of the NEMA for 50° C. rating.

SEC. 29. *Exciter.*—The generator shall be provided with a direct-connected, shunt-wound, self-excited exciter. The exciter frame shall be mounted directly on the generator, and the exciter armature shall be mounted on the extension of the generator shaft. The exciter shall be of sufficient capacity to supply the field excitation current of the geneator, when the generator is operated at normal kva output, 80 percent lagging power factor and normal rated voltage, and as required to meet the conditions for motor starting set forth in section 28.

SWITCHBOARD

SEC. 30. *Control switchboard and control equipment.*—The control switchboard and all necessary control and indicating equipment and auxiliaries shall be furnished, mounted, and wired complete by the contractor, as shown on the Authority's drawing. The following equipment shall be included:

a. Automatic voltage regulator to vary the exciter shunt field current in such manner as to maintain the a-c generator voltage essentially constant with variations in load from zero to 100 percent rated capacity of the machine. The regulator shall be General Electric Co. type GDA, or equal.

b. Exciter field rheostat, provided with suitable resistance and number of taps for setting the range of the regulator. The rheostat shall be arranged for rear-of-panel mounting with operating handle extending through the front of the panel.

c. Indicating instruments consisting of a-c voltmeter, a-c ammeter, d-c exciter voltmeter, d-c exciter ammeter. All instruments shall be Westinghouse type HY or HX, General Electric Co. type AD-6 or DD-6, Weston model 502 or 496, or equal.

d. Field switch and discharge resistor of the dead-front type arranged for front-of-panel control of generator field supply.

e. Generator circuit breaker, 3-pole, 600-ampere, 600-volt a-c. The circuit breaker shall be of the enclosed type, designed for flush mounting on ⅛-inch-thick switchboard panel, and shall be provided with studs and terminal lugs for connection to 750,000-cm cable. The breaker shall be Westinghouse type AB-1 or General Electric Co.'s type AF-1, or equal.

The control switchboard shall be of the dead-front, safety-enclosed type, with control and indicating instruments mounted on the front of the switchboard and with switching and protective equipment, buses, control wiring instrument transformers, terminal blocks, line terminals, cable supports, and clamps mounted in the rear section.

Operating mechanism handles, faceplates, door latches, instruments, and relays mounted on the front panels shall be designed for neat appearance and smooth finish.

Control wiring shall be installed to terminal blocks which shall be mounted at least 18 inches above the floor at the lower rear of the switchboards close to associated control conduits. All control terminal blocks shall be readily accessible for inspection and maintenance when the 440-volt power circuits are energized.

Clamp-type terminals shall be provided for all main, control, and ground cables leaving the board. Treated wood cleats on steel supports shall be provided for the Authority's cables from terminals to conduit. The cleats will be drilled by the Authority to receive the cables. Main and ground terminals shall be of the heavy, full-clamp type, Burndy or equal.

Structural steel sills drilled to fit the switchboard bases and equipped with anchor bolts and grout holes shall be provided for embedding the concrete floor.

The switchboard structure shall be of structural steel members and ⅛-inch-thick steel plates formed and welded. It shall be rigid and self-supporting.

Each exterior full-length panel and door shall be made from a single piece of ⅛-inch cold-rolled, stretcher-leveled steel, free from dents, cracks, or other defects, and braced when required to obtain necessary rigidity.

Each door shall be of the formed pan type with all four edges bent back and with corners welded and ground smooth to give the appearance of a beveled panel. Spacing between panels, doors, and trims shall be essentially uniform. Doors shall be equipped with suitable latches and heavy concealed loose-pin hinges which shall allow doors to swing at least 90° and shall permit removing doors when in the open position.

Ventilation shall be provided to the outside of the structure, and each ventilator shall be suitably screened against insects and rodents.

All metal panels shall be given rust-resisting treatment before any primer, paint, or lacquer is applied. Not less than one primer coat, one filler coat, and two finish coats of enamel shall be applied. The outside surfaces of the switchboard shall be black, and the inside surfaces shall be light gray. One quart of each color shall be furnished for each item for field retouching.

SHOP ASSEMBLY, TESTS, PAINTING

SEC. 31. *Shop assembly and test.*—The complete unit and accessory equipment shall be shop-assembled and tested. The unit shall be properly aligned and dowelled during assembly. The following tests shall be run:

a. The engine and generator shall be shop-tested to demonstrate that both units will fulfill the contractor's guarantees and the requirements of the specification.

b. The engine shall be tested at 425 horsepower for 2 hours, using water brake.

c. The combined engine and generator unit shall be tested at full load for 48 hours.

d. A test run shall be made to determine the maximum capacity of the combined unit at rated speed.

e. Test runs shall be made at rated speed to determine the fuel consumption per kilowatt-hour generated at ½, ¾, and full rated load of the generator. The fuel consumption shall not exceed that guaranteed by the contractor for such loads, and gasoline of no better quality than specified in section 11 shall be used during the test.

Certified copies of the tests shall be furnished the engineer. All tests shall be at the expense of the contractor. After satisfactory tests have been completed, the unit shall be mounted on skids and boxed for shipment. It shall be shipped as nearly completely assembled as is practicable.

SEC. 32. *Field tests.*—After installation the Authority will make such tests of the equipment as it deems necessary to demonstrate the compliance of the equipment with the requirements of the specifications. Included will be a test of the satisfactory starting of the pump motor as set forth in section 28.

SEC. 33. *Painting.*—All unfinished surfaces of the engine-generator unit shall be thoroughly cleaned, filled, and painted by the contractor in accordance with his usual practice.

PERFORMANCE GUARANTEES

The undersigned bidder guarantees that the equipment included in this proposal will develop operating characteristics as good as or better than the following:

(a) Maximum capacity at rated speed, unity power factor, __________ kw.
(b) Fuel consumption at rated speed, per kilowatt hour at the generator terminals (fuel as specified) __________ lb.
 At ½ load __________ lb.
 At ¾ load __________ lb.
 At rated load __________ lb.
(c) Efficiency of generator and exciter

	At unity power factor, percent	At 0.80 power factor, percent
At 50 percent rated output (150 kva)	__________	__________
At 75 percent rated output (225 kva)	__________	__________
At 100 percent rated output (300 kva)	__________	__________

(d) Regulation of generator

	Percent of rated voltage
At unity power factor	__________
At 0.80 power factor	__________
At 0.30 power factor	__________

(e) Exciter
 Rated voltage __________ volts
 Maximum voltage for 0.3 power factor condition __________ volts
 Rated current __________ amperes

PHYSICAL DATA

The following are a part of the physical characteristics of the equipment upon which the undersigned bidder's proposal is based:

Gasoline engine:
 Manufacturer __________
 Normal capacity at 1,200 rpm __________ brake horsepower
 Number of cylinders __________
 Cylinder bore __________ inches
 Material used in pistons __________
 Stroke __________ inches
 Size of exhaust pipe __________ inches
 Size of fuel inlet __________ inches
 Size of fuel outlet __________ inches
 Size of cooling water inlet __________ inches
 Size of cooling water outlet __________ inches
 Amount of cooling water required for engine __________ gpm
 Amount of cooling water required for exhaust jacket __________ gpm
Generator:
 Manufacturer __________
 Normal rated capacity at specified speed and voltage __________ kva

INSTALLATION OF COMPARABLE EQUIPMENT

The undersigned bidder has furnished equipment, practically identical with that covered by this proposal, to concerns, of the capacity and in the years as follows:

SPECIFICATION NO. 1628—FURNISHING AND INSTALLING AUTOMATIC ELECTRIC ELEVATOR, KENTUCKY PROJECT

(Reference drawings not included in this report)

GENERAL PROVISIONS

SECTION 1. *The requirement.*—Under this specification, the contractor shall design, furnish, deliver, install, and test in the powerhouse at Kentucky Dam one automatic elevator, including operating machinery, structural steel guides, elevator car, hoistway doors and frames, control equipment, and all other appurtenances and accessories, complete and ready for operation as hereinafter specified.

The work shall conform to applicable paragraphs of the American Standard Safety Code for Elevators, Dumbwaiters, and Escalators, approved by the American Standards Association, latest edition, except as modified by these specifications. All electrical equipment shall also conform to the standards of the AIEE, the NEMA, and the Underwriter's Electric Code.

The contractor shall furnish a certified statement that all of the above codes have been complied with.

SEC. 2. *General description.*—The elevator shall have selective collective automatic operation control by means of push buttons and shall be designed for operation with a motor-generator set and direct current, variable voltage control equipment.

The elevator shall have a rated live load capacity of 2,500 pounds at a rated speed of 300 feet per minute.

The total lift will be from elevation 302 at the bottom landing to elevation 383 at the top landing, a distance of approximately 81 feet, with intermediate landings at elevations 317, 332, 347, and 362.17. All hoisting machinery and control panels are to be installed in the machinery room above the shaft at elevation approximately 395.75.

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SEC. 3. *The engineer.*—Work under this specification shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specification.

SEC. 4. *Authority's drawings.*—The location for the elevator and the controlling details of the surrounding structure are shown on the accompanying drawing, which bears the general title "Kentucky Project—Powerhouse" and the individual designation as follows:

Drawing No.	*Title*
46N440–R1	Architectural—Elevator Shaft Sections and Details

Such supplementary drawings further detailing the above, as may be necessary, will be furnished by the Authority as required during the progress of the work.

The Authority shall be responsible for the general correctness of the dimensions shown on its drawing, but the contractor shall carefully check, in the field, all dimensions on drawing and schedules furnished by the Authority and shall advise the engineer of any errors or omissions discovered.

The Authority will furnish the contractor, without charge, three copies of the contract and specification and such number of prints of the Authority's drawing as may reasonably be required for the work.

SEC. 5. *Drawings to be furnished by the contractor.*—The contractor shall prepare complete assembly and detail drawings and wiring diagrams of the elevator giving all information necessary for operation and maintenance of the equipment and for demonstrating that it complies with the specifications. The drawings shall include but shall not be restricted to setting and location diagrams of parts embedded in the powerhouse structure which are to be furnished by the contractor but installed by the Authority, and also of parts accessory to the work under this specification which are to be furnished and installed by the Authority but whose exact locations are determined by the work included under this specification. Drawings shall be made in a manner to give clear, permanent reproductions, ink tracings being used if necessary. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract and to their respective elevator, and shall be signed by a responsible representative of the contractor.

Prints of each drawing shall be submitted in sextuplicate to the engineer for approval and in such sequence that the engineer will have all information necessary for checking.

The engineer will, within 10 days after receipt of prints of drawings for approval, forward one copy for the Contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."

The contractor shall make necessary corrections and revisions on drawings "Approved with Correction as Noted" and on drawings "Returned for Correction," and he shall submit prints for approval in the same routine as before. Time required for such revision of drawings and resubmission of prints will not entitle the contractor to any extension of time, but the engineer will examine and return such prints as promptly as possible.

Any work done or material ordered by the contractor prior to receipt of drawings "Approved" or "Approved with Correction as Noted" by the engineer shall be at the contractor's risk. When the corrections have been made on drawings "Approved with Correction as Noted," such drawings may be used for fabrication unless specifically stated otherwise by the engineer.

Approval by the engineer shall not relieve the contractor of the responsibility for the correctness of the drawings furnished by the contractor nor for their compliance with the specifications.

If, at any time before the completion of the work, changes are made necessitating the revision of approved drawings, the contractor shall make such revisions and proceed in the same routine as for the original approval.

Upon completion of work the contractor shall furnish the Authority one set of vandyke negatives on thin paper and five complete sets of prints of all drawings approved by the engineer, including all corrections and revisions made up to the time of completion of the work.

SEC. 6. *Work to be done and materials to be furnished by the Authority.*—The Authority will furnish the following material and do the following work for the elevator:

a. Provide the hoistway, including steel subframes for doorways.
b. Provide the machine room, including the concrete slab around the structural steel beams supporting the hoist equipment.
c. Install machinery supporting beams furnished by the contractor.
d. Furnish and install electrical conduits and junction boxes if embedded in concrete.
e. Provide service feeder wires and conduits for the hoisting machinery, terminating at the controller panel at a suitable location in the hoisting machinery room.
f. Provide a main powerline switch in machinery room with suitable protective devices.
g. Provide the telephone unit to be installed by the contractor.
h. Unload from railroad cars, transport to storage, provide storage, and transfer from storage to the point of installation all materials and equipment furnished by the contractor and to be included in the complete installation, and all erection equipment, materials, tools, and instruments required by the contractor under the work of this contract.
i. Furnish, within reasonable proximity to the work, compressed air at about 75-pound pressure, and 440-volt, 3-phase, 60-cycle current for power, and 110/220-volt, single-phase, 60-cycle current for lights and small power tools.

SEC. 7. *Work to be done and materials to be furnished by the contractor.*—Except as otherwise specified, the contractor shall furnish and install the elevator complete, including car, car enclosure, hoistway doors, hoisting machinery with motor and brake, control apparatus, governors, interlocks, protective devices, sheaves, cables, guide rails, rail supports, counterweight, buffers, anchor bolts, exposed electrical conduits, exposed junction boxes, electrical switches, conductors, and all other material, as specified or as necessary for satisfactory operation, and including all equipment, tools, and labor necessary for and incidental to the installing and testing of the elevator and auxiliary apparatus. The contractor shall furnish the machinery supporting beams for installation by the Authority over the tops of the elevator hoistway.

The contractor shall furnish diagrams or drawings as necessary for setting anchor bolts and other materials furnished by him and to be installed by the Authority.

Upon the completion of the work the contractor shall remove from the premises of the Authority all equipment and tools furnished by him for the work and shall leave the site of the work in a clean and orderly condition insofar as his work is concerned.

The contractor shall provide and install the initial charges of all oil and grease required throughout the equipment furnished by him.

SEC. 8. *Materials and workmanship.*—Materials used in the work shall be new, shall meet the requirements of an approved, recognized standard, and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust.

Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish, when not definitely specified, shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by this specification.

Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality. Like parts shall be interchangeable insofar as practicable.

SEC. 9. *Equipment.*—All equipment shall be new and of current model and latest design, shall be of standard, commercial, first-grade quality as to material, workmanship, and design, in accordance with the best engineering practice, and shall be such as has been proved to be suitable for the intended purpose, except that in minor details there will be permitted departures from previous designs, provided such departures are definite improvements over earlier designs.

Unless otherwise specified herein, all electrical equipment shall conform to the latest published standards of AIEE and NEMA as to all features of material, workmanship, design, and tests, where applicable.

SEC. 10. *Access to work.*—The engineer and his assistants and other agents of the Authoity shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and they shall have full facilities for unrestricted inspection of such materials or equipment.

SEC. 11. *Shop inspection and material orders.*—No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

The contractor shall, at his expense, prepare specimens and perform tests and analyses in accordance with standard practice, as required to demonstrate conformance of the various materials to the pertinent specifications. The contractor shall furnish to the engineer certified test reports in quadruplicate of all tests and analyses.

The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

The contractor shall furnish to the engineer and to the contracting officer a list of subcontractors and vendors with whom orders are to be placed for materials or equipment other than incidental fittings, fixtures, accessories, and supplies which will enter directly into the work of this contract. Triplicate copies of material or equipment orders and lists of contractor's stock material or equipment required in this contract shall be furnished to the engineer and one copy to the contracting officer.

All orders and stock lists shall state the specification designation under which the material is to be furnished and shall bear reference to the drawing and part number, if any, pertinent thereto. Orders shall also state that material is subject to inspection and testing and shall show the required date of delivery of the material to the contractor's plant.

The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

SEC. 12. *Preparation for shipment.*—The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

All finished surfaces shall be coated with an approved rust preventive.

MECHANICAL EQUIPMENT

SEC. 13. *Hoisting machinery.*—The hoisting machine shall be of the worm-geared traction type, consisting of an electric motor direct-connected through a worm gear to a driving sheave with brake, bearings, and accessory devices all mounted on a heavy cast-iron or steel bedplate.

The worm shall be of steel, forged integral with the worm shaft and provided with double-acting ball thrust bearings of ample capacity. The worm gear shall be a bronze ring or rim, with teeth machined from the solid, bolted and doweled or otherwise firmly secured to the gear spider.

Worm and gear shall run in oil, and a substantial metal casing shall be provided for both, sealed against entrance of dirt or water or the escape of lubricant and provided with adequate means for withdrawings, refilling, and indicating the level of lubricant.

All parts must be designed with factors of safety called for in the ASS Code.

The driving sheave shall be of semisteel, steel casting, or welded forging and thick enough to allow for regrooving if worn. The sheave shall have a diameter at least 40 times the diameter of the cable and shall be grooved for cables. Suitable guard shall be furnished to prevent cables from jumping off the sheave in case of accident.

The hoisting machine bearings shall be of the antifriction bearing metal type. Bearings shall be substantially mounted, shall be of ample size for the loads imposed, and shall be provided with oil reservoirs, automatic self-lubrication, oil gauges, and an approved means for draining and flushing bearings.

For babbitt bearings a pressure of not over 400 pounds per square inch shall be used, and for bronze a bearing pressure of not over 800 pounds per square inch must be used. The outer ends of bearings shall be closed with a suitable oiltight cap or plate. The inner ends of bearings shall be provided with oil wipers or the shaft shall be flanged to prevent oil leakage.

The bedplate for the hoisting machine shall be cast iron, with stiffening ribs to accurately maintain alignment, or shall consist of heavy structural steel shapes, securely welded together. Pads accurately planed or milled shall be used as seats for all parts secured to bedplate. All parts shall be bolted to the bedplate and doweled or otherwise so secured as to ensure permanent alignment.

SEC. 14. *Guides.*—The guides for cars and counterweights shall be planed steel tee sections, the car guides weighing not less than 15 pounds per lineal foot and the counterweight guides not less than 8 pounds per lineal foot. The guides shall be fastened in place with heavy clamps to brackets which are to be secured to the building structure. Guide rails are to be plumb and parallel, and all necessary shimming shall be done with metal securely held in place. The rails shall extend from approximately the bottom of the pit to the underside of the slab over the hoistway. The guides shall be thoroughly cleaned and smoothed before cars are put in operation.

SEC. 15. *Brake.*—The machine shall be provided with an electromagnet released, spring-set brake with two shoes independently actuated, secured to the motor frame or base, each having a spring of ample capacity to stop and hold the cars when carrying the maximum load. The springs shall be helical, operated in compression, and shall apply the brake when released by the magnet. The brake shall be so designed that the release shall be quick, and the brake application shall be automatically controlled by magnetic retardation to obtain quiet, smooth, and gradual stops with either light or loaded car. The circuit of the release magnet coil shall be opened upon the normal stopping of the car, and directly or indirectly by the various safety devices by current failure, and upon the failure of any of the several units of the equipment to function in the proper manner for safe operation of the car. Brake shoes shall be lined with suitable fireproof friction material and run free with a minimum clearance.

SEC. 16. *Governor and safety.*—A centrifugal governor equipped with an electric switch shall be provided for the car. The switch shall be operated by the governor at not more than 120 percent of the rated car speed, to open motor and brake control circuits and to bring the car to a smooth stop and apply the brake in the usual manner. If the opening of the above switch and application of the brake does not stop the car, or if for any other reason the speed of the car in the downward direction increases to 140 percent of the rated speed, the governor shall, in addition to opening the switch, lock governor rope and set safety guide grips. The governor shall be located so as to be protected from accidental injury and shall be provided with a metal cable guard. There shall be a metal tag on the governor stating rated car speed, the point at which guide grips begin to operate in conjunction with the governor, and size, material, and construction of governor cables.

SEC. 17. *Cables.*—The elevator is to be provided with cables of size and number sufficient to provide a factor of safety in accordance with "Safety Code for Elevators, Dumbwaiters, and Escalators," as approved by ASA latest edition. Contractor must definitely indicate on his shop drawings the number of cables and size of cables proposed to be used, together with name of manufacturer, type, strength in tons, and the proper working load in tons. Cables are to be of special traction steel consisting of not less than six strands each, with hemp centers. The ends of cables are to be properly turned, backed, and socketed, and secured to the hitch plates with swivel thimble shackles, and suitable screw adjustments are to be provided so tension of cables may be readily equalized.

SEC. 18. *Compensating chains.*—Suitable compensation shall be provided on the car to compensate for the varying weight of the hoisting cables due to the changing location of the cars in the hatchways. This varying weight shall be fully compensated by chains securely fastened to the bottom of the car frames and to the bottom of the counterweights, and shall be of such size and weight as will correspond to the weight of the hoisting cables.

SEC. 19. *Lubricators.*—If sliding guides are furnished, automatic-adjustable lubricators shall be provided on the car and counterweights for the lubrication of the guide rails. The lubricators shall be actuated by the car movement. Drip cups shall be provided at all places where oil drip may occur. A grease gun for supplying grease to the sheaves, bearings, and the like shall be furnished. Roller guides of approved design will be accepted in place of sliding guides.

SEC. 20. *Counterweights.*—Counterweights equal to approximately the weight of each complete car and 40 percent of the specified live load shall be provided. The counterweights shall be made of cast-iron sections fitted to a frame. The frames shall be constructed of steel or wrought-iron shapes securely bolted, riveted, or welded together with adjustable guide shoes provided on both sides at top and bottom. The weight sections shall be held within the frames by not less than two heavy tie rods which shall pass through completely enclosed holes in each weight section. Slots will not be accepted as a means of securing weights. All nuts used on tie rods shall be provided with locknuts and cotter pins. Each weight section shall be solid. Any cracked sections shall be replaced. The counterweight frames shall be provided with suitable fastenings for the buffer and compensating chain to be secured to the bottom member and the top hitch to be secured to top member.

SEC. 21. *Buffers.*—Oil-cushioned buffers shall be provided under car and counterweights. The buffers shall bring the car and counterweights to a gradual stop at extreme limits of travel beyond terminal landings more than a safe distance. All necessary supports for the buffers shall be provided by the contractor. The buffers shall be of a type suited to the space conditions existing at the site and must be adequate to absorb, within the limits of the moving parts, all the energy of car or counter-balance when traveling at 140 percent of the rated speed, and the average retardation shall not exceed 32.2 feet per second. Suitable gauges or other approved means shall be provided for determining the level of oil in the buffers.

ELEVATOR CAR AND DOORS

SEC. 22. *General.*—The car shall have a minimum inside floor area of approximately 33 square feet, and the actual dimensions shall be in accordance with the contractor's standards, within the limits established by the shaft outline shown on the drawing.

SEC. 23. *Car frame and platform.*—The car-supporting frame shall be made of structural steel, arc-welded and bolted together, and of sufficient strength to meet the requirements of the ASS code rules 210 and 310. Car frame shall be equipped with guide shoes or guide rollers.

The platform shall consist of a frame built of structural steel shapes securely riveted and bolted or welded together. It shall be provided with substantial vertical faces flush with the outer edges and extending a sufficient distance below the floor so there will be no horizontal openings into the hoistway while the car is within the landing zones and while the hoistway doors are wholly or partially open. The floor shall consist of a wooden platform securely bound with angle framing, mitered and welded at the corners. The platform shall have a 1-inch spruce base, fireproofed underneath with No. 25 gauge sheet iron, over which shall be placed 1⅞-inch spruce nailing floor and a top layer of ⅞-inch tongue-and-grooved hard pine not over 4 inches wide, driven up tight, blind-nailed and surface-nailed. Each layer shall be laid diagonally and at right angles to the preceding layer. The surface of the top layer shall be carefully sanded to a smooth finish and covered with best grade of rubber tile, not less than one-quarter inch thick, over a layer of asphalt-saturated felt, laid in accordance with the manufacturer's specifications, and finished smooth on the exposed surface. Entrance to car shall be provided with a feralun one-piece threshold flush with the floor.

SEC. 24. *Car enclosure.*—The car enclosure shall be constructed of steel plates and shapes and shall be equal in design to the standards of the Otis Elevator Co. as stated below:

Car design—Design No. 1733-3.
Panels—Steel, lacquered a solid color as selected.
Panel stripes—½-, ⅜-, and 1⅜-inch-wide lacquer.

Entrance columns—Steel, lacquered a solid color as selected.
Grille—Brass, dull chrome-plated.
Canopy, soffit, and trough—Steel, lacquered a solid color as selected.
Light—Indirect lighting on two sides of car with lumiline lamps and fittings.
Kickplate of car—Design No. 2, 16-gauge brass dull chrome-plated.
Emergency exit—Removable type in ceiling.
Cutouts—For standard operating and signal fixtures.
Car door—Hollow metal, flush panel, lacquered a solid color as selected, with brass, 16-gauge dull chrome-plated kickplate the same height and finish as the kickplate in the car.
Handrail—Brass, dull chrome-plated, No. 6377D, extending continuously around corners of car.
Floor covering—Rubber tile, 9- by 9-inch squares, ¼ inch thick, marbleized pattern, color as selected.

The car shall be constructed of No. 14 gauge polished-furniture steel, and the paneling shall be reinforced with vertical stiffening angles spaced not more than 12 inches on centers. The car shall be rigidly fastened to the platform by through bolts extending from suitable fastenings on top of the car to the underside of the platform. The car shall be equipped with brass, dull chrome-plated certificate frame, manufacturer's nameplate on which the car loading capacity in pounds and number of passengers are stated, hooks for protective pads, and one set of protective pads.

SEC. 25. *Car door.*—The car shall be equipped with two-speed flush-panel, hollow-metal doors of No. 12 gauge polished-furniture steel, properly reinforced for hangers, floor guides, closer arms, and other hardware, and provided with sheave-type hangers suitable for power operation. The doors shall be filled with cork or other suitable sound-deadening material and shall be equipped on the car side with brass, 16 gauge, dull chrome-plated kickplates, beveled on the top only.

SEC. 26. *Car and hoistway door operators.*—A motor-driven electric operator shall be provided to open and close the car door and hoistway doors when the car is at a landing. The car door and hoistway door at any landing shall be opened and closed simultaneously at a minimum speed of 1 foot per second and without slam. Door movements shall be cushioned or checked at both limits of travel. An electro-mechanical interlock shall be provided at each opening to prevent the operation of the elevator unless all doors are closed and locked. An electric contact shall be provided on the car door to prevent the operation of the elevator unless the car door is closed.

The door operator shall be so arranged that in case of interruption or failure of electric power from any cause the doors can be readily operated by hand from within the car. Emergency devices and keys for opening the doors from the landing shall be provided as required by applicable codes.

The doors shall open automatically when the car is leveling at the respective landing and shall again close after a predetermined time interval has elapsed. A "door open" button shall be provided in the car, the momentary pressure of which shall reverse the motion, reopen the doors, and reset the time interval.

The car door shall be provided with a protective device extending the full height and projecting beyond the front edge of the door. This device shall be so arranged that should it touch a person or any obstruction in its path while the door is closing it shall automatically cause both the car door and the hoistway door to return to the open position. The doors shall remain open until the expiration of a time interval and then close automatically. The pressing of a car button, once the doors are fully open, shall cause the doors to close immediately.

SEC. 27. *Handhole.*—A handhole for access for the safety release mechanism, if required, shall be provided in the floor of the car, and a suitable holder and wrench shall be placed in the machinery room. The handhole shall have a white bronze or brass frame and cover with a satin finish.

SEC. 28. *Emergency exit.*—The car shall be provided with an emergency exit in the ceiling. The exit shall be not less than 18 inches wide and approximately 400 square inches in area. The cover shall open outward and

shall be held in place by thumbscrews or other suitable means, so arranged that the cover can be removed from the outside or the inside of the car. Any equipment mounted on top of the car shall be so located as not to interfere with proper access to and from the emergency exit.

SEC. 29. *Hoistway doors and frames.*—The contractor shall furnish and install the hollow-metal hoistway doors at elevations 302.0, 317.0, 332.0, 347.0, 362.17, and 383.00, together with pressed-steel frames and all hardware in connection with the doors, including kickplates, thresholds, glass, washers, shims, nuts, bolts, screws, and other accessories incidental thereto, all to be complete and ready for service, as shown on drawing 46N440 and as specified herein.

The Authority will furnish and install the steel subframes for all the doors.

All steel used in the construction of the hoistway doors and frames shall be of the best grade of open-hearth, full cold-rolled, full-pickled, double-annealed, stretcher-leveled sheet steel, entirely free from scale and pits.

The doors shall be two-speed, flush-panel doors, of the type shown on the drawings, and shall be thoroughly reinforced on the inside to withstand shock, as well as normal usage, without sagging or warping. Provision shall be made for such reinforcement as may be necessary for connecting electrical interlocks and other hardware and equipment. The main parts of the doors shall be made of No. 12 gauge steel. The bottom of the doors shall be equipped with a high-carbon steel guide. The doors shall be filled with cork or other suitable sound-deadening material.

Kickplates shall be provided on the corridor side and shall be brass, 16 gauge, dull chrome-plated, beveled on the top only. Screws for securing kickplates to the doors shall be brass dull chromium-plated, with counter-sunk oval heads.

The pressed-steel frames shall be made of No. 14 gauge steel and equipped with a hinged and latched cover. Frames shall be securely fastened to the steel subframes.

SEC. 30. *Thresholds.*—The contractor shall furnish and install thresholds and steel facia plates for the hatchway at each floor. Thresholds shall be equal to feralun as manufactured by the American Abrasive Metals Company.

SEC. 31. *Car finish.*—The entire interior of the car shall be given a 6-coat pyroxylin-base lacquer finish. The finish shall consist of a priming coat of oil-base primer, one coat of glazing preparation, one coat of oil-base sanding surfacer, and three coats of pyroxylin-base lacquer of color as selected by the engineer.

SEC. 32. *Finish of hatchway doors and frames.*—All hatchway doors and frames shall be cleaned of all oil, grease, rust, dirt, or other foreign matter, and all inaccessible parts given a coat of rust-resisting paint before fabrication. After fabrication, all accessible surfaces shall be given a coat of rust-resisting enamel, baked on. Doors and frames shall then be given a coat of primer and sanded smooth and repainted where sanding removed any of the rust-resisting enamel.

The finish coats of paint for the hatchway doors and frames will be done by the Authority.

SEC. 33. *Finish of car frame and platform.*—After assembly the car frame and platform shall be given two coats of red-lead paint and two coats of light-gray paint.

SEC. 34. *Hardware and trim.*—All exposed hardware shall be brass, dull chrome-plated.

SEC. 35. *Samples.*—The contractor shall submit three samples of each of the following:

a. Samples of finish for kickplates.
b. Samples of finish for hardware.
c. Samples of finish for car.
d. Samples of rubber tile.

If satisfactory, the Authority will return one sample of each kind, marked with its approval. If not approved, the contractor shall submit other samples until such approval is obtained.

ELECTRICAL EQUIPMENT

SEC. 36. *General.*—The electrical equipment, control, and interlocks shall be furnished complete for a fully automatic elevator. It shall provide smooth and uniform acceleration and retardation, automatic slowdown and stopping at all landings independent of the loading within its rated capacity.

The electrical system shall consist of a motor-generator and exciter set or sets, hoist motor and brake, automatic push-button control, automatic leveling devices, automatic door operators, terminal and final limit switches, car lighting, signal lights, and telephone.

The telephone will be supplied by the Authority but shall be installed by the contractor.

SEC. 37. *Electric power.*—The 440-volt, 3-phase, 60-cycle power for operation of the motor-generator set and 115-volt, single phase, 60-cycle power for car lighting, and signal lights will be supplied by the Authority as required.

SEC. 38. *Motor-generator set.*—A motor-generator set shall be provided for the elevator consisting of a 440-volt, 3-phase, 60-cycle motor driving a direct-current generator. The set shall be of open-frame type, of compact design, and of ample capacity for all operating and test conditions of the hoist motor, and the temperature rise of the set shall not exceed 50° C. above an ambient of 40° C. when operating continuously.

The motor-generator set shall be located in the elevator machinery room and shall be mounted on a cushioning device to completely insulate it from the floor. The motor and its controller may be designed for across-the-line starting.

SEC. 39. *Hoist motor.*—The hoist motor shall be direct-current, reversible, open-frame type, designed especially for elevator service for operation from the motor-generator set. The motor shall be rated 1 hour 50° C. rise above an ambient of 40° C.

SEC. 40. *Control and operation.*—The hoist motor control equipment shall be of the variable-voltage or unit-multivoltage type, consisting of the proper magnetic contactors, relays, and other devices necessary to accomplish the control of the elevator. All switches, etc., shall be magnet-operated of substantial construction and mounted on panels of ebony asbestos supported by means of angle iron or pipe framework. All connections shall be made at rear of board, and controllers shall be so arranged as to govern the direction of car travel, starting, acceleration, deceleration, stopping, and speed of the car. The control panel shall also be connected to all the electrical safety devices hereinafter specified.

The motor-generator set shall be provided with an automatic starter. The starter shall be of the across-the-line type. It shall be provided with inverse-time thermal overload relays in each line and with under-voltage, phase failure, and ground protection.

The elevator shall have selective, collective automatic control. The control shall include a series of push buttons in the car, numbered to correspond to the various landings, UP-DOWN push buttons and indicating light at intermediate landings, and single buttons and light at terminal landings. All buttons shall be placed in flush-mounted cases, finished dull chromium.

The system shall be so designed that on pressing of one or more car or landing buttons the car shall start automatically, provided the interlock circuits are established, and shall stop at the first floor for which a car button has been pressed or for which a landing button has been pressed corresponding to the direction in which the car is traveling. The car shall stop at all landings for which such calls have been registered, and these stops shall be made in the order in which the landings are reached by the car, irrespective of the sequence in which the buttons have been pressed, provided the button for a given landing has been pressed sufficiently in advance of the arrival of the car at that landing to permit the stop to be made.

The control shall be so arranged that if no car buttons have been pressed and the car starts up in response to several down calls, the car shall travel to the highest down call first and then reverse to collect the other down calls. The up calls shall be collected in the same way when the car starts down in response to up calls by first stopping for the lowest up call registered.

Furthermore, if the car has stopped in response to the pressing of a landing button and a passenger pressed a car button for the corresponding direction, and within a predetermined interval of time after the stop, the car shall carry the passenger in that direction regardless of other landing calls registered.

If, while the car is making its upward trip, down landing buttons are pressed, no effect shall obtain during the up trip although the calls shall remain registered. After the last passenger traveling in the up direction has left the car and the interlock circuit is established by all doors being closed, the elevator shall start automatically and respond to the down landing calls. Likewise, the downward trip of the car shall not be affected by up landing button calls, but such calls shall remain registered and be answered on the next upward trip. A time limit relay shall be provided, arranged to hold the car at the landing at which it has stopped, for a predetermined period of time before it will again start automatically in response to other calls. The opening of the hoistway or car door shall prevent movement of the car until both are closed again.

An emergency stop switch shall be provided in the car to interrupt the power supply and apply the brake independently of the regular operating devices. The opening of the stop switch shall not cancel the registered calls, and after this switch is again closed the car shall continue to answer its calls.

The motor-generator set shall automatically start on the pressure of any car or landing button and shall continue to run for a predetermined time interval after the last call has been answered, when it shall automatically stop until another call is registered.

SEC. 41. *Automatic leveling.*—The elevator shall be completely equipped with an approved automatic self-leveling device that will automatically bring the car to a position within ½ inch of the exact level with any floor for which either a car or landing button has been pressed.

The self-leveling shall, within its zone, be entirely independent of the operator and shall be accomplished by satisfactory and efficient means.

SEC. 42. *Terminal and final limit switches.*—The elevator shall be provided with devices constructed and designed to function as follows:

a. A device such that the car, as it approaches either terminal or any intermediate landing as selected by the push-button control, will slow down and come to a smooth stop automatically at the selected landing. If this device is located on the car and operated by cams in the hatchway, it shall be enclosed type and be practically noiseless in operation. If located in the machinery room, it shall be mechanically connected to and driven by the car, and means shall be provided that the car will be promptly stopped upon any failure of the driving mechanism.

b. Limit switches at the top and bottom travel limits of the hatchway. These switches shall be independent of any other stopping device, shall be positively operated by the car and shut off all power from the motor, and shall apply the brakes and prevent further operation of the car in the direction of overtravel.

c. An overspeed switch shall be provided and mounted in connection with the governor. All the above devices shall be of rugged construction, substantially mounted.

SEC. 43. *Conductors, cables, and conduits.*—The Authority will furnish and install the main disconnect switch in the hoist machinery room, all embedded conduits with power conductors from the station service switchboard to the disconnect switch, all embedded conduits between the switch, the control panels, the motor-generator set, and the hoist motor. Also the lighting and telephone conduits with conductors will be provided by the Authority to junction boxes in the hatchway near elevations 342 and 343, respectively, for extension by the contractor to the elevator cab. The contractor shall furnish and install all exposed conduits and all conductors required for controls and for a complete installation beyond the main switch and junction boxes listed above.

All conductors shall be installed in zinc-coated rigid steel conduit, except the flexible cable connections to the car and such connections between controllers and other equipment as may be so short as to be self-supporting. All conduits shall terminate in approved conduit fittings. All conduit fittings in the elevator pit shall be watertight. All rigid conduit shall be supported at

not more than 10-foot intervals, and all outlet and junction boxes shall be supported independently. Separate cables and conduits shall be used for car lighting, control circuits, and telephone. The conductors running to safety circuits shall be in separate cables and conduit. Not less than four spare conductors shall be incorporated in the flexible traveling cable in the hoistway. In all multiple conductor cables, each conductor shall have a distinctive marking.

The power conductors shall be of capacities not less than as prescribed by National Electric Code. All conductors except flexible cable connections to car shall be soft-drawn copper insulated with 35 percent performite rubber compound with 600-volt insulation and with tape and braid.

All conductors to the car shall be of the highest grade extra-flexible flameproof cables running from the bottom of the car to approved outlets in the hoistway. The strength of the cables shall be such as to provide high factors of safety for the service to which they will be subjected. All conductors No. 10 Awg and larger shall be stranded, and connections shall be made by solderless-type terminals. No splicing of conductors will be permitted.

Traveling cables shall be installed in such manner that there will be no strain on the electrical connections, and the ends of each cable shall be fastened to an approved terminal block having identifying number to facilitate tracing and replacement. The terminal blocks shall be mounted in approved junction boxes.

Sec. 44. *Wiring diagrams.*—Complete wiring diagrams and photographs or cuts showing all wearing parts of motor-generator set, hoist motor, and controller, neatly framed under glass, shall be furnished and installed in the elevator machine room.

TESTING AND PAINTING

Sec. 45. *Tests.*—A drop test shall be made on the elevator before the cables are permanently attached or the cab has been installed. This test shall consist of cutting loose the car platform with a test load equal to the weight of the cab plus two-thirds of the contract load of the elevator. The total distance through which the car will fall shall not be less than 6 feet nor more than 12 feet. At the end of the drop the car platform shall not be out of level more than ½ inch in each foot of distance between guide rails.

After the elevator has been completely installed, the contractor shall demonstrate, to the entire satisfaction of the engineer, the proper operation of the equipment in compliance with this specification. The contractor shall also determine the heating and insulation resistance of the motors.

All tests shall be made in the presence of the engineer.

Sec. 46. *Painting.*—After completion of the tests and satisfactory demonstration of its compliance with the specification, all machinery and metalwork, except noncorrodible or enameled surfaces, shall be neatly painted. Metalwork to be installed in the hoistway shall be given one shop coat of red-lead paint and after installation shall be given one additional coat of red-lead paint and two coats of light-gray paint. Electrical conduits and junction boxes shall be given two coats of asphaltum varnish. All equipment in the machine room shall be given one shop coat of paint, smoothed off, followed by one coat of gray machine enamel and after installation shall be given one or more coats of machine enamel of the color directed. The car shall be painted as specified.

EQUIPMENT DATA

Bidder shall set forth the following facts with respect to the equipment he proposes to furnish:

Motor for Elevator

Make ____

Type ____

Maximum running current with elevator loaded to rated capacity ____________

____

Rated speed ____________________________________

Motor-Generator Set for Elevator

Make ______
Synchronous speed ______
Rated horsepower of motor, continuous rating 50° C. rise ______
Starting current of motor-generator set ______
Rated current of main generator, continuous rating ______
Rated voltage of main generator ______
Rated current of exciter, generator, continuous rating ______
Rated voltage of exciter generator ______

SPECIFICATION NO. 6327—STATIONARY ELECTRIC MOTOR DRIVEN AIR COMPRESSOR FOR DRAFT TUBE EVACUATION, HIWASSEE PROJECT

GENERAL PROVISIONS

1. The requirement

a. Under these specifications, the contractor shall design, furnish, and deliver one electric-motor-driven, flange-mounted, stationary, 2-stage air compressor, of Y-type or L-type construction, having a capacity of not less than 540 cfm at 100-psig discharge pressure.

b. The air compressor unit shall be complete as specified herein and also in accordance with the specifications and drawings submitted by the contractor.

c. Should any conflict arise between the specifications herein contained and the specifications and drawings submitted by the contractor, the former shall rule in all essential requirements and, where not otherwise determined by the engineer, also in the matters of detail.

d. The Authority will install all the apparatus to be furnished hereunder, furnish all electric wiring and electric conduit required to connect the equipmet to the power supply, and furnish all necessary anchor bolts.

e. The Authority will furnish all piping and fittings to connect to the equipment to be furnished, including the piping between the air compressor and the aftercooler, and cooling water supply.

2. Service conditions

a. The air compressor unit shall be designed and constructed for continuous general plant service under conditions as hereinafter set forth.

b. The capacity of the unit as specified shall be a minimum, and the contractor shall furnish a standard unit of the capacity specified, or that standard unit of his manufacture having a capacity greater than but most nearly conforming to the capacity specified.

c. The controlling requirements and limiting conditions for the compressor are as follows:

Compressor construction—Y- or L-type
Rated capacity at sea level and 68° F. air (see note)—540 cfm
Terminal pressure, psig—100
Maximum compressor speed, rpm—600
Maximum piston speed, fpm—700
Motor power supply—440 volts, 3 phase, 60 cycles
Cooling water available:
  Pressure, psi—30
  Temperature, F. maximum—85

NOTE.—The "capacity" shall be the actual volume of air compressed and delivered by the compressor, expressed in cubic feet per minute, at intake temperature and pressure.

3. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the Engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

4. Drawings to be furnished by the contractor

a. The contractor shall furnish assembly and detail drawings, wiring diagrams, instructions, and cuts of the work in such number and detail as necessary for installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications. Drawings shall be submitted by the contractor as promptly as possible and in such sequence as to permit the Authority to design the attendant equipment and structures.

b. Such drawings shall include but shall not be limited to the following:

(1) Foundation drawings of all parts set into or coming in contact with concrete, showing method of supporting and method of anchoring into concrete.
(2) Detailed drawings of all parts connecting to or related to equipment supplied by other manufacturers or to equipment furnished by the Authority.
(3) Piping drawings and wiring diagrams.
(4) Plans, elevations, sections, and details of the compressor.
(5) Details of all parts of equipment which may require adjustment or are subject to wear. Also drawings showing methods of lubricating parts.
(6) Details of automatic control systems.
(7) Complete operating instructions.

c. All drawings shall show the material, dimensions, bolting, and such other information as may be necessary to demonstrate compliance with the requirements of the specifications.

d. The contractor shall permit the engineer to examine such of the contractor's shop drawings as may be necessary to enable him to determine the efficiency of the contractor's design. The contractor shall provide the engineer with copies of such of his design data as may be required by the engineer for the purpose.

e. Four prints of each drawing shall be submitted to the engineer for approval and in such sequence that he will have all information necessary for checking.

f. The engineer will, within approximately ten days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."

g. The contractor shall make necessary corrections and revisions on drawings marked "Approved with Correction as Noted" and on drawings marked "Returned for Correction," and he shall submit prints for approval in the same routine as before. The engineer will examine and return all prints as promptly as possible.

h. Any work done or material ordered by the contractor prior to receipt of drawings "Approved" or "Approved with Correction as Noted" by the engineer shall be at the contractor's risk.

i. After print of any drawings has been returned "Approved," the contractor may release to his shop for production all the parts covered by the approval.

j. Drawings shall be made in a manner to give clear, permanent reproductions. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract, and shall be signed by a responsible representative of the contractor.

k. Approval by the engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

l. If, at any time before the completion of the work, changes are made necessitating the revision of approved drawings, the contractor shall make such revisions and proceed in the same routine as for the original approval.

m. After approval of drawings, the contractor shall furnish six complete sets of prints of all approved drawings and instructions, including all corrections and revisions made up to the time of approval.

5. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

b. Approved material meeting the requirements of the appropriate ASTM specifications shall be employed.

c. Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust.

d. Workmanship shall be first-class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

e. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

6. Work to be done and materials to be furnished by the Authority and others

a. Foundations.
b. Erection.
c. Electric wiring beyond the terminal of the electrical equipment.
d. Piping except as specified.
e. Field painting.
f. Motor starter.
g. Condensate traps.

7. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such materials or equipment.

b. The contractor shall, if required, furnish suitable office space, equipment, and telephone facilities to enable the Authority's representative to perform his official duties.

8. Shop inspection and material orders

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected unless the engineer authorizes inspection to be made elsewhere.

b. The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

c. The contractor shall furnish to the engineer three copies of material or equipment orders, as issued, and lists of the contractor's stock material or equipment required in this contract, with one additional copy of each order or list to the contracting officer.

d. All principal orders and stock lists shall state the specifications designation and shall bear reference to the drawing and part number, if any, pertinent thereto. Orders shall also state that material is subject to inspection and testing and shall show the required date of delivery of the material to the contractor's plant.

e. The acceptance of any material or equipment by the engineer shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

9. Shop assembly and tests

a. The contractor shall assemble, in the shop, and test the compressor, as necessary to demonstrate conformance with the requirements of the specifications as to capacity, pressure, and other operating characteristics.

b. Certified copies of tests of identical compressors previously tested will be accepted in lieu of tests for such equipment furnished under these specifications.

c. Routine tests shall be made in accordance with NEMA Standard MG1–4.29 on the motor. Witness of tests by the Authority will not be required. Complete test data for an exact duplicate motor shall also be included.

d. The contractor shall furnish the Authority seven certified copies of the results of both tests called for above. Test reports shall include the serial number of the compressor and the motor and complete name plate data.

10. Marking

a. All parts or units of assembly shall be marked or tagged with piece marks. Marks shall be in accordance with approved erection drawings, shall be clearly legible, and so placed as to be readily visible when the part is

being erected in the field. All pieces weighing more than one ton shall have the approximate weight marked thereon.

b. Connecting parts assembled in the shop shall, before dismantling for shipment, be match-marked to facilitate erection in the field. All parts or assembly of parts shall also be so marked as to identify them with this contract.

11. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

DETAILED SPECIFICATIONS

12. Requirements

a. The air compressor shall consist of a heavy-duty, water-cooled, 2-stage, double-acting, vertical Y-type or L-type, cross-head-type air compressor, driven by a flange-mounted electric motor. The compressor shall be provided with a water-cooled intercooler. The intercooler shall be located between the two stages and shall be complete with supports and any necessary pipe and fittings or chambers for connection to the compressor cylinders. The motor rotor shall be mounted on an extension of the crankshaft. The motor stator shall be bolted directly to the compressor frame.

b. The crankshaft shall be counterweighted and shall be provided with a double row of ball or roller bearings or floating sleeve-type bearings at each end.

13. General

a. The air compressor unit shall be a standard product of manufacturer regularly engaged in the production of equipment of the nature called for by these specifications and shall be of a design that has proved reliable and satisfactory in the service intended. The compressor unit shall be capable of continuous operation under the service conditions set forth in section 2, without injurious heating, and shall operate without objectionable noise or vibration. Sufficient flywheel effect shall be incorporated in the compressor to ensure steady and smooth operation under intermittent loading and unloading conditions.

b. The contractor shall furnish with the compressor a horizontal, water-cooled aftercooler, combined intake air filter and silencer, necessary gauges, and all accessories and controls required for a complete air compressor unit to operate satisfactorily in the service intended.

c. The contractor shall furnish a suitable angle-type thermometer and a relief valve for mounting in the Authority's discharge line from the air compressor. The relief valve shall be factory-set to relieve at 115 psi and shall be of ample size to protect the compressor in case of failure of the automatic controls.

d. The compressor parts shall be accurately machined and balanced to produce smooth operation. The air valves shall be of the plate or flat-strip type, and shall be designed to produce a large effective area and shall be quiet in operation. All other moving parts of the compressor shall be completely enclosed in a dustproof, oiltight housing.

e. The compressor unit shall have an approved automatic lubricating system for all moving parts, including the pistons.

14. Automatic control

a. The compressor shall have an automatic start and stop control, which shall include an unloading device to unload the compressor when it is stopped and maintain that condition until the motor is again up to speed. The compressor shall unload to atmospheric pressure to prevent starting the machine under load. The control for the compressor shall include the necessary pressure switch, General Electric CR2922G1A, or equal, which shall be of the gauge type, enclosed and suitable for mounting on a steel switchboard panel. The pressure switch shall operate the 440-volt a-c closing circuit of the motor starting contactor. The control coils of the pressure switch shall also be for 440 volts a.c. The panel and motor starter will be furnished by the Authority. The pressure switch shall be adjustable within an operating range of from

32 to 128 psi and shall be adjustable to operate with a change in pressure of 5 psi. The necessary time delay device shall be provided to hold the compressor unloaded until the motor is up to speed. If for separate mounting, this device shall be suitable for mounting on the steel switchboard panel. A solenoid- or air-operated valve shall be furnished with the compressor to shut off the cooling water when the compressor is not running and to open when the compressor is started. If solenoids are used they shall be wound for 440-volt, 60-cycle current and shall be insulated with insulation especially impregnated to resist moisture and shall be enclosed in metal housing having adequate space for wiring connections. The compressor shall be provided with dual control for manually changing the automatic start and stop control to a constant speed control, which shall unload the compressor when the pressure reaches a predetermined amount and load the compressor when the pressure drops below a predetermined amount, without stopping the motor.

15. Aftercooler

a. The compressor shall be provided with a horizontal, straight pipeline type, water-cooled aftercooler of shell and tube design with condensate separator capable of cooling the rated compressed-air capacity of the compressor to a temperature of not more than 20° F. higher than the incoming water temperature. The air inlet and outlet connections to the aftercooler shall be at opposite ends of the unit. Both aftercooler and compressor shall be provided with a cast-iron sight flow funnel with inlet and outlet tappings for standard iron pipe threads to be used in the cooling water discharge line. The contractor shall furnish all pipe and fittings between the aftercooler and its sight flow and between the compressor and its sight flow.

16. Air filter and silencer

a. The air compressor shall be provided with a combined air filter and silencer equal to those manufactured by Burgess-Manning Co. or Air-Maze Corp.

17. Motor

a. The motor shall be squirrel-cage, 3-phase, 440-volt, 60-cycle, constant-speed, dripproof type, with class A stator insulation and conforming to NEMA Standard MG1–1949. The motor shall have sufficient capacity for all conditions of starting and continuous operation which its compressor may impose, with a temperature rise not exceeding 40° C. above an ambient temperature of 40° C. Motor-rated name plate horsepower shall not be exceeded with the compressor operating at rated capacity specified under section 2.

b. The motor shall be designed for full-voltage starting, low starting current, and normal starting torques in accordance with NEMA design B.

c. Stator coils and leads shall be thoroughly insulated, securely supported, and braced for full voltage start, and the completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles. A suitable conduit box shall be provided for the leads.

d. The rotor core or spider shall be accurately fitted, keyed, and secured to the shaft. The squirrel-cage winding shall be of die-cast aluminum or shall be of copper or alloy bars securely attached to the end rings so as to form a mechanical and electrical bond equivalent to the solid bar.

e. Where bearings are incorporated in the motor they shall be ball or roller type, sealed against the entrance of dust or escape of lubricant, and provided with adequate means for flushing the old lubricant when introducing new lubricant.

f. The motor shall be tested in accordance with section 9.

18. Painting

a. The compressor shall be thoroughly cleaned. All exposed unfinished surfaces of ferrous metals shall be filled and painted in accordance with the Contractor's practice.

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and

size, and to have performance characteristics as good as or better than that shown below. In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

Compressor

Manufacturer ______
Type ______
Capacity based on 68° air at sea level (see note), cfm ______
Piston, diameter and stroke, inches ______
Compressor speed, rpm ______
Piston speed, fpm ______
Power required at specified gauge pressure and the above capacity, hp ______
Volumetric efficiency, percent ______
Air inlet diameter, inches ______
Air outlet diameter, inches ______
Cooling water required at specified pressure and temperature, gpm:
- Cylinders ______
- Intercooler ______

Piston material ______
Cylinder interior surface finish ______
Temperature of discharge air from compressor, °F ______
Weight of compressor, less motor, pounds ______

NOTE.—The "capacity" shall be the actual volume of air compressed and delivered by the compressor expressed in cubic feet per minute, at intake temperature and pressure.

Air Silencer and Filter

Manufacturer ______
Catalog No ______
Air outlet diameter, inches ______

Aftercooler

Manufacturer ______
Catalog No ______
Air inlet diameter, inches ______
Air outlet diameter, inches ______
Cooling water required at specified pressure and temperature, gpm ______
Temperature of discharged air, °F ______
Weight of aftercooler, pounds ______
Overall length of aftercooler, inches ______

Motor

Manufacturer ______
Type and frame ______
Rated capacity, hp ______
Full-load speed, rpm ______
Full-load current, amp ______
Locked-rotor current, amp ______
Power factor, full load ______
Efficiency, full load, percent ______
Locked-rotor torque, percent of full-load torque ______
Breakdown torque, percent of full-load torque ______
Weight of motor, pounds ______

Control Equipment

Pressure governor manufacturer and catalog No ______
Pressure governor, minimum differential setting, psi ______
Pressure governor, adjustable range, psi ______
Unloading device, type and manufacturer ______
Discharge thermometer, type and manufacturer ______
Type of cooling water supply valve ______
Size of cooling water supply valve ______
Compressor discharge relief valve, size, manufacturer and catalog No ______

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SPECIFICATION NO. 6239—PORTABLE ELECTRIC-MOTOR-DRIVEN AIR COMPRESSOR, CHATUGE PROJECT

GENERAL PROVISIONS

1. The requirement

a. Under these specifications, the contractor shall furnish and deliver the following air compressor:

Item 1. One electric-motor-driven, portable air compressor having a capacity of not less than 85 cfm at 100 psi.

a. The air compressor unit shall be complete as specified herein and also in accordance with the specifications and drawings submitted by the contractor.
b. Should any conflict arise between the specifications herein contained and the specifications and drawings submitted by the Contractor, the former shall rule in all essential requirements and, where not otherwise determined by the engineer, also in matters of detail.

2. Service conditions

a. The air compressor unit shall be designed and constructed for continuous service under conditions as hereinafter set forth.
b. The capacity of the unit as specified shall be a minimum, and the contractor shall furnish a standard unit of the capacity specified, or that standard unit of his manufacture having a capacity greater than but most nearly conforming to the capacity specified.
c. The controlling requirements and limiting conditions for the compressor are as follows:

Rated capacity at sea level and 68 degrees air, cfm minimum (see note); 85.
Terminal pressure, psi gage; 100.
Available power; 440 volts, 3 phase, 60 cycles.
Maximum synchronous speed of motor, rpm 1,200.

Note.—The "capacity" shall be the actual volume of air compressed and delivered by the compressor, expressed in cubic feet per minute, at intake temperature and pressure.

3. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

4. Drawings to be furnished by the contractor

a. The contractor shall furnish assembly and detail drawings, wiring diagrams, instructions, and cuts of the work in such number and detail as necessary for operation and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.
b. Such drawings shall include but shall not be limited to the following:

(1) Plans, elevations, sections, and details of the compressors.
(2) Details of all parts of equipment which may require adjustment or are subject to wear. Also drawings showing methods of lubricating parts.
(3) Complete operating instructions.
(4) Unloading and wiring diagrams.

c. All drawings shall show the material, dimensions, bolting, and such other information as may be necessary to demonstrate compliance with the requirements of the specifications.
d. Two prints of each drawing shall be submitted to the engineer for approval and in such sequence that he will have all information necessary for checking.
e. The engineer will, within approximately 10 days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Ap-

proved," "Approved with Correction as Noted," or "Returned for Correction."

f. The contractor shall make necessary corrections and revisions on drawings marked "Approved with Correction as Noted" and on drawings marked "Returned for Correction," and he shall submit prints for approval in the same routine as before. The engineer will examine and return all prints as promptly as possible.

g. Any work done or material ordered by the contractor prior to receipt of drawings "Approved" or "Approved with Correction as Noted," by the engineer shall be at the contractor's risk.

h. Drawings shall be made in a manner to give clear, permanent reproductions. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract, and shall be signed by a responsible representative of the contractor.

i. Approval by the Engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

j. After approval of drawings, the contractor shall furnish seven complete sets of prints of all approved drawings, including all corrections made up to the time of approval.

5. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

b. Approved material meeting the requirements of the appropriate ASTM specifications shall be employed.

c. Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust.

d. Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

e. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

6. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such materials or equipment.

b. The contractor shall, if required, furnish suitable office space, equipment, and telephone facilities to enable the Authority's representative to perform his official duties.

7. Shop inspection and material orders

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected unless the engineer authorizes inspection to be made elsewhere.

b. The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

c. The acceptance of any material or equipment by the engineer shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

8. Shop assembly and tests

a. The contractor shall assemble, in the shop, and test the compressor as necessary to demonstrate conformance to the requirements of the specifications as to capacity, pressure, and other operating characteristics.

b. Certified copies of tests of identical compressors previously tested will be accepted in lieu of tests for such equipment furnished under these specifications.

c. Routine tests shall be made in accordance with the latest NEMA standards for the motor. Witness of tests by the Authority will not be required.

d. The contractor shall furnish the Authority seven certified copies of the results of the tests called for above. Test reports shall include the serial number of the motor and complete name plate data.

9. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit.

DETAILED REQUIREMENTS

10. General

a. The air compressor unit shall be a standard product of a manufacturer regularly engaged in the production of equipment of the nature called for by these specifications and shall be of a design that has proved reliable and satisfactory in the service intended. The compressor unit shall be capable of continuous operation at maximum load without injurious heating, and shall operate without objectional noise or vibration.

11. Portable air compressor

a. The compressor shall be fully air-cooled, or air-cooled by fluid medium in a radiator, and driven by a direct-connected electric motor. Fully air-cooled compressors having two stages shall be provided with an intercooler. An adequate fan shall be furnished to provide the necessary air circulation for compressor and cooler. If air-cooled by water in a radiator the cylinders shall be fully water-jacketed on head and body. An adequate water pump shall be provided for circulating the cooling water through the water passages of the compressor and radiator. A suitable fan shall be furnished to provide the necessary air circulation through the radiator.

b. The body of the cylinders shall have ample thickness of metal to permit reboring.

c. The crankshaft bearings may be of an approved ball or roller type. Steel- or bronze-backed babbitted crankshaft bearings will also be acceptable. The crankcase shall be oiltight and dustttight construction. Adequate splash feed lubricators shall be provided for the cylinders and crankshaft bearings.

d. A combined intake silencer and air filter shall be provided.

e. An enclosed unloading device shall be provided which shall unload the compressor to atmospheric pressure when the discharge pressure exceeds an adjustable predetermined amount, and shall load the compressor when the pressure drops below an adjustable predetermined amount. Means shall be provided for manually operating the unloader to unload the compressor when starting the motor and until it is up to speed.

f. The compressor shall be provided with the necessary intermediate and discharge pressure gauges, safety valves, and all other accessories, necessary or customary, for a complete compressor of the type herein specified.

g. A suitable air receiver shall be provided, having a capacity of not less than 5 cubic feet.

h. The entire compressor unit shall be mounted on a sturdy truck having four wheels with pneumatic rubber tires and antifriction bearings, a towing tongue, and lifting hooks for handling by a crane. A substantial metal housing shall be provided to protect the entire unit from the weather. Doors shall be provided in the housing as necessary to afford ready access to the compressor unit.

i. The control equipment shall conform to the standards of NEMA, shall meet the requirements of the National Board of Fire Underwriters, and shall consist of a service entrance receptacle with plug, a safety switch, a magnetic starter, a push-button station, and a limit switch on the unloader operating handle, together with all interconnecting wiring and conduit.

j. The service entrance receptacle shall be Crouse-Hinds AR648, or equal, 60 amperes, 600 volts, 4-pole polarized, with the ground wire solidly bonded to the compressor frame and cover. The Crouse-Hinds APJ6485 plug for this receptacle shall have cable entrance suitable for 4-conductor, No. 6, type "W" portable cable.

k. The safety switch shall be enclosed, 3-pole, fusible, rated 60 amperes, 575 volts. The switch shall be so located on the frame as to be within reach from outside the housing by means of one of the access doors.

l. The magnetic starter shall be 3-pole, enclosed, rated not less than the connected horsepower at 440 volts, 3 phase, and shall be provided with manual reset thermal overload device having characteristics corresponding to the thermal characteristics of the motor windings. Sufficient auxiliary contacts shall be provided to allow the control specified.

m. The push-button control station shall be heavy duty, 2 button, momentary "make" and "break" contacts, rated 600 volts, with "start" and "stop" designations. It shall be mounted on the cover near the unloader operating handle, operable from the outside.

n. The limit switch on the unloader operating handle shall be heavy duty, rated 600 volts, and the contacts shall "make" when in the unloading position.

o. All internal power and control connections shall be provided. Wires shall be insulated with oil base rubber, with insulation rated at 600 volts, and shall be run in approved conduit. The control shall be so wired as not to permit starting the motor unless the unloader operating handle is in the unloading position, and shall be so wired as to provide undervoltage protection.

12. Motor

a. The motor shall be squirrel-cage, 3-phase, 440-volt, 60-cycle, constant speed, splashproof type, with class A stator insulation and conforming to NEMA Standard MG1–1949. The motor shall have sufficient capacity for all conditions of starting and continuous operation which the compressor may impose, with a temperature rise not exceeding 50° C. above an ambient temperature of 40° C. Motor-rated name plate horsepower shall not be exceeded with the compressor operating at rated capacity specified under section 2.

b. The motor shall be designed for full voltage starting, low starting current, and normal starting torque in accordance with NEMA Design B.

c. Stator coils and leads shall be thoroughly insulated, securely supported and braced for full-voltage start, and the completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles.

d. The rotor core or spider shall be accurately fitted, keyed, and secured to the shaft. The squirrel-cage winding shall be of die-cast aluminum or shall be of copper or alloy bars securely attached to the end rings so as to form a mechanical and electrical bond equivalent to the solid bar.

e. Bearings shall be ball or roller type, sealed against the entrance of dust or escape of lubricant, and provided with adequate means for flushing the old lubricant when introducing new lubricant.

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and size, and to have performance characteristics as good as or better than that shown below. In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

Compressor

Manufacturer	______
Type	______
Capacity based on 68° air at sea level (see note), cfm	______
Cooling medium	______
Piston diameter and stroke, inches	______
Volumetric efficiency, percent	______
Number of stages	______
Number of cylinders	______
Piston speed, feet per minute	______
Compressor speed, rpm	______
Power required at specified gauge pressure and the above capacity, hp	______
Type of crankshaft bearings	______
Temperature of discharge air, °F	______
Capacity of air receiver	______

NOTE.—The "capacity" shall be the actual volume of air compressed and delivered by the compressor, expressed in cubic feet per minute, at intake temperature and pressure.

Motor

Manufacturer	____
Type and frame	____
Rated capacity, hp	____
Full-load speed, rpm	____
Full-load current, amp	____
Locked-rotor current, amp	____
Power factor, full load	____

Complete Unit

Total weight, pounds	____

Control Equipment

Manufacturer's name and catalog number of the following:

Unloading device	____
Magnetic starter	____
Electric service entrance receptacle	____

SPECIFICATION NO. 6310—ELECTRIC-MOTOR-DRIVEN HORIZONTAL CENTRIFUGAL DOUBLE-SUCTION WATER PUMPING UNIT, PICKWICK PROJECT

GENERAL PROVISIONS

1. The requirement

a. The work covered by these specifications under item 1 comprises furnishing, testing, and delivering one direct-connected, double-suction, horizontally split case, electric-motor-driven horizontal centrifugal pumping unit for treated water service, having a capacity of not less than 1200 gpm against a total dynamic head of 275 feet.

b. All equipment shall be new and shall be of commercial, first-grade quality as to material and workmanship in accordance with the best engineering practice.

c. The following specifications of the issue in effect on date of invitation for bids shall form a part of these specifications, but only those portions shall apply which are specifically referred to elsewhere in these specifications:

Hydraulic Institute, Section B—Centrifugal Pump
NEMA MG1–1949—Motor and Generator Standards.

2. General arrangement

a. The pump will operate on emergency service, furnishing fire protection water service to transformers and oil circuit breakers on the powerhouse roof. All water will be filtered water.

b. The required characteristics and limiting conditions for the construction of the pumping units are as follows:

Number of units; 1.
Design capacity, each unit, at least, gpm; 1,200.
Design total dynamic head, feet; 275.
Shut-off head, maximum, feet; 320.
Minimum operating head, TDH, feet; 240.
Suction conditions; flooded.
Water temperature, maximum F.; 85.
Rotation, looking from the motor end; clockwise.

c. The design of the pump shall be such that a "flat" head capacity characteristic curve results.

3. Location of the Pickwick hydro plant

a. This plant is located about five miles north of the northeast corner of the State of Mississippi on the Tennessee River.

4. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

5. Drawings and data to be furnished by the contractor

a. Within 30 days after notice of award of contract the contractor shall furnish assembly and detail drawings, instructions, and cuts of the work in such number and detail as necessary for installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.

b. Such drawings and data shall include but shall not be limited to the following:

(1) Outline, plan, and elevations of unit showing all principal dimensions, anchor bolt sizes, and location of bolts.
(2) Details of all piping connections showing location, size, flange dimensions, bolt circles, and size and number of studs or bolts.
(3) Motor outline drawing.
(4) Cross-section drawings, showing item numbers for each part, to facilitate ordering replacement parts.
(5) Complete installation and operating instructions.
(6) Approximate characteristic curve of the pump (see also section 11, paragraph b).

c. All drawings shall show the material, dimensions, bolting, and such other information as may be necessary to demonstrate compliance with the requirements of the specifications.

d. The contractor shall permit the engineer to examine such of contractor's shop drawings as may be necessary to enable him to determine the efficiency of the contractor's design. The contractor shall provide the engineer with copies of such of his design data as may be required by the engineer for the purpose.

e. Four prints of each drawing shall be submitted to the engineer for approval and in such sequence that he will have all information necessary for checking.

f. The engineer will, within approximately 10 days after receipt of prints for approval, forward one copy to the contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."

g. The contractor shall make necessary corrections and revisions on drawings marked "Approved with Correction as Noted" and on drawings marked "Returned for Correction," and he shall submit prints for approval in the same routine as before. Time required for such revision of drawings and resubmission of prints shall not entitle the Contractor to any extension of time, but the engineer will examine and return such prints as promptly as possible.

h. Any work done or material ordered by the contractor prior to receipt of drawings "Approved" or "Approved with Correction as Noted" by the engineer shall be at the contractor's risk.

i. After print of any drawing has been returned "Approved" the contractor may release to his shop for production all the parts covered by the approval. When the approval covers an assembly or group of parts, the contractor shall furnish one print of each shop drawing of such parts to the engineer at the time when issued for production.

j. Drawings shall be made in a manner to give clear, permanent reproductions.. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract and shall be signed by a responsible representative of the contractor.

k. Approval by the engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

l. If, at any time before the completion of the work, changes are made necessitating the revision of approved drawings, the contractor shall make such revisions and proceed in the same routine as for the original approval.

m. After approval of drawings the Contractor shall furnish six complete

sets of prints of all approved drawings, including all corrections and revisions made up to the time of approval.

6. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to the several purposes in accordance with best engineering practice.

b. Approved material meeting the requirements of the latest ASME or ASTM standards shall be employed unless otherwise specified.

c. Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust. Workmanship shall be first class and shall be done by workmen skilled in their various trades.

d. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

7. Work to be done and materials to be furnished by the Authority and others

a. Foundations and foundation bolts.
b. Field painting.
c. Electric wiring.
d. Bolts, nuts, and gaskets for discharge and suction flanges.
e. Control and starting equipment.
f. Installation of the pumping unit.

8. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and they shall have full facilities for unrestricted inspection of such materials or equipment.

9. Shop inspection and materials orders

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications, and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

10. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. The equipment shall be thoroughly cleaned. All exposed unfinished surfaces of ferrous metals shall be filled and painted with one coat of an approved paint.

c. All finished surfaces shall be coated or otherwise protected with an approved rust preventive. All exposed flanged faces shall be adequately protected.

11. Shop assembly and tests

a. Before shipment the pumping unit shall be completely assembled in the shop and operated as necessary to ensure that all dimensions and clearances are in accordance with the drawings and to ensure the proper fit of mating parts. All parts of the pumping unit subject to hydraulic pressure in service shall be given a hydrostatic pressure test of not less than 150 percent of the specified total dynamic pressure without showing any indication of weakness or leakage.

b. The Contractor shall furnish to the Authority six copies of a certified characteristic curve for the pump which has been developed from tests of the pump furnished under this contract or from tests previously made on a similar pump which met the requirements of the specifications for the pump furnished.

c. Routine test as listed in NEMA Standard MG1–4.24 (regardless of horsepower rating) shall be performed on the motor. These tests will not be witnessed by the Authority.

d. The contractor shall furnish the Authority seven certified copies of the results from the motor tests called for above. Test reports shall include the serial number of motor and complete name plate data.

e. The approval of the factor tests shall in no way relieve the contractor of his obligations under these specifications.

12. Field tests

a. As soon as practicable after the completion of the work under these specifications, the Authority will make, at its own expense, such tests as it deems desirable to demonstrate the compliance of the equipment with the requirements of these specifications and the specifications and guarantees of the contractor.

b. The contractor will be permitted to have a representative present at all such tests.

13. Painting

a. All parts of the pumping unit shall be painted in accordance with the manufacturer's standard practice.

DETAILED SPECIFICATIONS

14. Pump—General

a. The pumping unit shall be a standard product of a manufacturer regularly engaged in the production of such pumping units and shall be of a design and construction that has proved reliable and satisfactory for continuous operation. The unit shall be designed so as to be readily assembled or dismantled. The design and workmanship shall be such that the pumping unit will operate satisfactorily for the intended service without undue wear on any parts and without objectionable vibration.

b. The pump shall conform to the applicable paragraphs of the Centrifugal Pump Section of the Standards of the Hydraulic Institute except as otherwise specified herein, and shall be provided with all standard accessory parts, including air cocks, drain cocks, water seal rings and piping, and special wrenches and other tools necessary for installation, operation, and maintenance of the units.

15. Pump characteristics and motor capacity

a. The operating characteristics of the pump and the rated capacity of its motor shall be such that the motor shall not exceed its rated temperature rise or nameplate horsepower capacity when operating under any head condition between the minimum specified and shutoff. At heads less than the minimum specified, a brake horsepower of not over 10 percent greater than the motor nameplate rating may be utilized.

16. Pump casing

a. The casing shall be of close-grained cast iron, horizontally split, double-suction type, so designed as to produce smooth flow with gradual changes in velocity. Suction and discharge openings shall be cast integral with the lower half of the casings and shall be flanged, faced and drilled 125-pound ASA Standard. Renewable wearing rings shall be provided in the casing.

b. The volute shall be provided with suitable air vent and drain cocks. The extended ends of the case for bearing supports shall be provided with tapped drain connections.

17. Impeller

a. The impeller shall be of bronze of the enclosed type, machined where necessary to fit or to maintain close clearances, and with all waterways finished smooth, mechanically and hydraulically balanced, securely fastened to the shaft, and locked against lateral movement.

18. Shaft, bearings, stuffing boxes, and coupling

a. The shaft shall be made of forged or heat-treated, high carbon or alloy steel of ample size, ground and polished and protected throughout its entire

length within the case, except that portion covered by the impeller, by removable bronze or noncorrodible alloy steel wearing sleeves securely fastened to the shaft and extending through the stuffing boxes, and held in place with sleeve nuts or other approved means. A water deflector shall be provided on the shaft at the bearing to prevent gland leakage water entering bearing housing.

b. Deep stuffing boxes shall be provided in the pump casing, with proper packing for the service securely held in place by retainer rings on the inside and a rugged bronze gland on the outside. Lantern rings of noncorrodible metal shall be provided in the stuffing boxes with seal water piped to them from the volute.

c. Bearings shall be of the ball, roller, or ring oiling plain type, enclosed in splashproof and dustproof housings and provided with adequate means of lubrication by grease or by oil and provided with adequate means for flushing out the old lubricant when introducing the new. If oil lubricated, the bearings shall be provided with sight gauges for indicating the oil level in the housings.

d. A flanged coupling shall be furnished for joining the pump and motor shafts. This coupling shall be of the flexible type such as the rubber bushing and pin type or other approved equal.

19. Base plate

a. The pump and motor of the unit shall be mounted on a rigid, common base plate of cast iron or welded structural steel, with a raised lip around the outside and a drain connection or other approved means for the collection and disposal of leakage.

20. Motor

a. The motor shall be squirrel-cage, constant-speed, full-voltage start, dripproof type, NEMA design B, with class A stator insulation and conforming to NEMA Standard MG1–1949. The motor shall have sufficient capacity for all conditions of starting and continuous operation which its pump may impose, with a temperature rise not exceeding 40° C. above an ambient temperature of 40° C.

b. Motor shall be 440 volts, 3 phase, 60 cycles.

c. The motor shall have stator coils and leads thoroughly insulated, securely supported and braced for full-voltage start and no-voltage transfer from a preferred to an emergency source. The completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles. A suitable conduit box shall be provided for the leads.

d. The rotor core or spider shall be accurately fitted, keyed, and secured to the shaft. The squirrel-cage winding shall be of die-cast aluminum or shall be of copper or alloy bars securely attached to the end rings so as to form a mechanical and electrical bond equivalent to the solid bar.

e. Bearings for motor shall be of the split-sleeve type, sealed to prevent the leakage of oil and to exclude dust and moisture. The bracket design shall permit bearing replacement without disturbing the lower half.

f. See section 11 for motor tests.

GUARANTEED DESIGN AND PERFORMANCE DATA

The undersigned hereby guarantees that the performance and characteristics of the equipment offered by him under this proposal will be as stated in the following tabulation:

Pump

Manufacturer	________
Catalog No. of pump	________
Full-load speed, r.p.m	________
Diameter of discharge outlet, inches	________
Diameter of suction inlet, inches	________
Shut-off head, feet	________
Capacity at specified total dynamic head, g.p.m	________
Efficiency at the above capacity and specified total dynamic head, percent	________
Power required at the above capacity and specified total dynamic head, b.h.p	________

Power required at the minimum head specified, b.h.p	
Maximum power required between pump breakdown head and shutoff, b.h.p	
Type of bearings	
Material in shaft wearing sleeves	
Material in shaft	
Manufacturer of flexible coupling	
Type of flexible coupling	
Material in casing wearing rings	

Motor

Manufacturer	
Type and frame No	
Rated horsepower	
Full-load speed, r.p.m	
Full-load current, amp	
Locked-rotor current, amp	
Power factor at 100, 75, and 50 percent rated horsepower	
Efficiency at 100, 75, and 50 percent rated horsepower	
Bearings, type	
Locked-rotor torque at rated volts in percent of normal	
Pull-up torque at rated volts in percent of normal	
Breakdown torque at rated volts in percent of normal	

Complete Unit

Overall efficiency at specified total dynamic head and specified capacity, percent	
Weight, pounds	

In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

SPECIFICATION NO. 4189—ELECTRIC-MOTOR-DRIVEN HORIZONTAL CENTRIFUGAL CLOSE-COUPLED END SUCTION WATER PUMPING UNIT, HALES BAR PROJECT

GENERAL PROVISIONS

1. The requirement

a. Under these specifications the contractor shall design, furnish, and deliver, f.o.b. cars at the plant site, the following electric-motor-driven, close-coupled, end suction, side discharge, centrifugal pumping unit for strained raw water service as hereinafter specified and as shown by the contractor in data submitted with his bid:

(1) Under item 1 shall be furnished one electric-motor-driven pump having a capacity of 500 gallons per minute against a total dynamic head of 245 feet.

b. All equipment shall be new and shall be of commercial, first-grade quality as to material and workmanship in accordance with the best engineering practice.

c. The equipment shall conform to the latest standards of the Hydraulic Institute insofar as practicable, except as hereinafter modified.

2. General arrangement

a. The required characteristics and limiting conditions for the construction of the unit is as follows:

Item No.	1
Number	1
Design capacity, gallons per minute, minimum	500
Design total dynamic head, feet[1]	245
Maximum total dynamic head, feet[2]	255
Minimum total dynamic head, feet	200

[1] The maximum efficiency of the pump should be as close to the design head as feasible.
[2] The shutoff head should be materially greater than the maximum head.

3. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

4. Drawings and data to be furnished by the contractor

a. Within 30 days after notice of award of contract the contractor shall furnish two copies of assembly and detail drawings, instructions, and cuts of the work in such number and detail as necessary for installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.

b. Such drawings shall include but shall not be limited to the following:

(1) Outline, plan, and elevation of units showing all principal dimensions and location of anchor bolts.
(2) Complete installation and operating instructions.
(3) Characteristic curves of the pumps.
(4) Cross section drawings of the pumps showing all parts and parts lists for future parts replacement.
(5) Motor outline prints.

c. The engineer will, within approximately 10 days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."

d. Upon approval of all data the contractor shall furnish the Authority six complete sets of prints of all drawings approved by the engineer, including all corrections and revisions made up to the time of completion of the work.

e. Approval by the engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

5. Work to be done and materials to be furnished by the Authority and others

a. Foundations and anchor bolts.
b. All piping and valves except as otherwise specified.
c. Field paintings.
d. Electric wiring.
e. Bolts, nuts, and gaskets for flanges.
f. Starting equipment for electric motor.
g. Installation of the equipment.

6. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. All finished surfaces shall be coated or otherwise protected with an approved rust preventive. All exposed flanged faces shall be adequately protected. All screwed connections shall be plugged.

7. Shop assembly and tests

a. Before shipment the pumping unit shall be completely assembled in the shop and operated as necessary to ensure that all dimensions and clearances are in accordance with the drawings and to ensure the proper fit of mating parts. All parts of the pumping unit subject to hydraulic pressure in service shall be given a hydrostatic pressure test of twice the shutoff head produced by the pump when operated at its service speed, without showing any indication of weakness or leakages.

b. The contractor shall furnish to the engineer eight certified copies of a characteristic curve for the pump which has been developed from tests of the individual pump or from tests previously made on a similar pump which met the requirements of the specification for the pump finished.

DETAILED SPECIFICATIONS

8. Pump, general

a. The pump shall be a standard product of a manufacturer regularly engaged in the production of pumps of the type specified herein and shall be of a design and construction that has been proved reliable in the service intended. The pump shall conform to the applicable paragraphs of the Centrifugal Pump Section of the Standards of Hydraulic Institute except as otherwise specified herein, and shall be provided with all standard accessory parts, including air cocks, drain cocks, water seal rings and piping, and special wrenches and other tools necessary for the installation, operation, or maintenance of the pump.

9. Pump characteristics and motor capacity

a. The operating characteristics of the pump and the rated capacity of its motor shall be such that the motor shall not exceed its rated temperature rise or nameplate horsepower capacity when the unit is operating under any head condition between shutoff and the minimum specified.

10. Pump casings

a. All casings shall be of close-grained cast iron. Renewable wearing rings shall be provided in the casings. Casings shall be so designed as to produce smooth flow with gradual changes in velocity. Suction and discharge openings shall be faced and drilled 125 pounds ASA standard. The casing shall be split vertically to facilitate removal of the impeller.

11. Impellers

a. The impellers shall be of the semienclosed or enclosed type, made of bronze, machined where necessary for fit or to maintain close clearance, and with all waterways finished smooth, mechanically and hydraulically balanced, keyed to the shaft, and locked against lateral movement.

12. Shaft and stuffing box

a. A stuffing box of ample depth shall be furnished in the pump casing and provided with a bronze water seal ring properly connected to the pressure side of the impeller.

b. Provision shall be made to prevent water, leaking from the pump stuffing box, from entering the motor.

c. A rigid cast iron connecting piece shall be provided, connecting the pump casing and the inboard motor bell, to ensure the rigidity and permanent alignment of the unit. This connecting piece shall be so constructed as to afford convenient access to the pump stuffing box.

d. The pump and motor shaft shall be integral and made of forged or heat-treated, high carbon or alloy steel of ample size, ground and polished and protected by removable bronze or alloy steel wearing sleeves securely fastened to the shaft and extending through the stuffing box.

13. Motor

a. The motor shall conform to NEMA Standard MG1–1949.

b. The motor shall be squirrel cage, 440 volts, 3 phase, 60 cycles, normal torque, low-starting current, NEMA Design B, dripproof frame, full-voltage start.

c. The motor shall have adequate capacity and operating characteristics for all conditions of starting and continuous operation which the equipment to which it is connected may impose, with a temperature rise not exceeding 50° C. above an ambient temperature of 40° C.

d. Bearings shall be adequate to withstand the combined loads of the rotating parts of both pump and motor and shall be designed to counteract any thrust produced by the pump under all conditions of service.

e. Routine tests shall be made on each motor in accordance with NEMA MG1–4.24. The test report shall also state that air gap, conditions of bearings, and rotor balance have been inspected and are satisfactory. Witness of tests by the Authority will not be required. Six certified copies of each test report shall be furnished.

GUARANTEED DESIGN AND PERFORMANCE DATA

The undersigned hereby guarantees that the performance and characteristics of the equipment offered by him under this proposal will be as stated in the following tabulation:

Pump

Item No	______ 1 ______
Manufacturer	______
Catalog or figure No	______
Full-load speed, revolutions per minute	______
Size of suction inlet, inches	______
Size of discharge outlet, inches	______
Shutoff head, feet	______
Capacity at specified total dynamic head, gallons per minute	______
Efficiency at above capacity and specified total dynamic head, percent	______
Power required at the above capacity and specified total dynamic head, brake horsepower	______
Maximum power required at any head between shutoff and the minimum total dynamic head specified, brake horsepower	______

Motor

Item No	______ 1 ______
Manufacturer	______
Type and frame No	______
Rated horsepower	______
Full-load speed, revolutions per minute	______
Full-load current, amperes	______
Locked-rotor current, amperes	______

Complete Pumping Unit

Overall efficiency at the specified total dynamic head and capacity, percent	______
Total weight pump and motor, pounds	______

In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

SPECIFICATION NO. 4264—INSULATING AND LUBRICATING OIL PURIFYING UNITS, BOONE PROJECT

GENERAL PROVISIONS

1. The requirement

a. The work covered by these specifications comprises the designing, furnishing, and delivery of oil purifying units for the power plant of the Boone project as follows:

(1) One stationary insulating oil purifying unit of combined centrifuge and filter press type, with a capacity of not less than 600 gallons per hour.

(2) One stationary lubricating oil purifying unit of the centrifuge type, with a capacity of not less than 350 gallons per hour.

b. The contractor shall furnish all equipment complete and ready for installation, as herein specified, and also in accordance with specifications and drawings submitted by him.

c. The Authority will install all the apparatus to be furnished hereunder, and will furnish all electric wiring and electric conduits required to connect the equipment to be furnished by the contractor to the power supply. The Authority will furnish all necessary supports and anchor bolts for the purifying units.

2. General description

a. The insulating oil purifying unit will be used to purify and recondition oil from transformers and circuit breakers in the switchyard. The unit shall be of the stationary type and will be permanently connected into a piping system arranged for the transfer of the insulating oil for purifying and for storage. Dirty insulating oil will be taken from a storage tank, passed through the purifier, and discharged into a clean oil storage tank, or it will be taken from the tank of a circuit breaker or a transformer, passed through the purifier, and recirculated to the tank of the oil circuit breaker or transformer.

b. The insulating oil will have approximately the following characteristics:

Viscosity at 40° F., SSU; 180.
Viscosity at 100° F., SSU; 63 maximum.
Freezing point; —40° F. or less.
Flash point (open-cup test); 266° F. or more.
Fire point (open-cup test); 293° F. or more.
Dielectric strength (original) as measured by AIEE standard method; 30,000 volts, minimum.
Specific gravity at 60° F.; 0.84 to 0.90.
Temperature of oil entering purification unit; 40° F. minimum to 100° F. maximum.

c. The insulating oil purifying unit shall be complete with centrifuge, centrifuge motor, two motor-driven pumps, electric heaters, filter press, automatic temperature control, thermometers, gauges, meters, screens, valves, piping, electrical equipment, and all accessories for satisfactory operation of such a purifier. The contractor shall furnish an electric filter paper drier having sufficient capacity to accommodate and dry thoroughly not less than 240 sheets of filter paper in one operation. It shall be complete with thermometers, electric heaters, and regulating switches.

d. The lubricating oil purifying unit will be used to purify and recondition lubricating oil from the governor system and the thrust bearings of the main generators in the powerhouse. It shall be of the stationary type and will be permanently connected into a piping system arranged for the transfer of the lubricating oil for purifying and for storage. Dirty lubricating oil will be taken from a storage tank, passed through the purifier, and discharged into a clean oil tank, or it will be taken from a governor sump tank or thrust bearing oil housing, passed through the purifier, and recirculated to the governor sump tank or to the thrust bearing oil reservoir.

e. The lubricating oil will have approximately the following characteristics:

Viscosity at 60° F., SSU; 850.
Viscosity at 110° F., SSU; 170.
Specific gravity at 60° F.; 0.9.
Temperature of oil entering purification unit; 60° F. minimum to 110° F. maximum.

f. The lubricating oil purifying unit shall be a complete, self-contained, and enclosed unit, with centrifuge, centrifuge motor, motor-driven pumps, or pump, electric heaters, automatic temperature control, thermometers, strainers, meters, gages, valves, piping, electrical equipment, and all accessories necessary for satisfactory operation of such a purifier.

3. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

4. Drawings to be furnished by the contractor

a. The contractor shall submit for approval two copies of dimensional drawings, cuts, or illustrations covering all items that he is furnishing under this contract. The engineer will, within 10 days after receipt of drawings, cuts, or illustrations for approval, forward one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Cor-

rection." After approval the contractor shall submit six copies of all data submitted under this contract.

b. The drawings and information submitted by the contractor shall include:

(1) Detail and arrangement drawings of the equipment in elevations and plan, giving all important dimensions, location, and size of all connections, etc.
(2) Cross sectional drawings of the complete equipment, showing all parts for future spare parts identification.
(3) Motor outline and dimension sheets and wiring diagrams for all electric equipment.
(4) Oil flow diagram of complete equipment.
(5) Complete sets of installing and operating instructions neatly bound in folders.

5. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with the best engineering practice.

b. Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish, when not definitely specified, shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

c. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

6. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where materials or equipment are being made or prepared for use under this contract, and shall have full facilities for unrestricted inspection of such materials or equipment.

7. Shop inspection and material orders

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications, and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

8. Marking

a. All parts or units of assembly shall be adequately marked. Marks shall be in accordance with drawings or other lists, shall be clearly legible, and so placed as to be readily visible when the part is being erected in the field.

9. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

DETAILED SPECIFICATIONS

10. Purifying units

a. Each purifying unit shall be a standard product of the contractor, of a design which has been proved reliable and satisfactory in the service intended.

b. The minimum capacity of the insulating oil purifying unit, without the use of filter press, shall be 600 gallons of insulating oil per hour and not less than the capacity guaranteed by the contractor in his bid.

c. The minimum capacity of the lubricating oil purifying unit shall be 350 gallons of lubricating oil per hour, and shall not be less than the capacity guaranteed by the contractor in his bid.

11. Centrifuge

a. The centrifuge of each unit shall be designed to produce a high centrifugal force. It shall be substantial in construction and free from any unbalanced condition, and shall operate without objectionable noise or vibration. It shall be equipped with adequate bearings and lubricated to ensure easy running and long continuous service. Each centrifuge shall have an enclosed oil inlet and outlet with sight glasses or inspection ports and a positive means of determining when any of the oil entering the purifier is bypassing the bowl. Each shall be easy to dismantle, clean, and assemble, and so designed as to permit quick adjustment to purify oils of different specific gravities or water content. The collecting pan and bowl housing shall be substantial in design. The centrifuge shall be completely enclosed and constructed so that there will be practically no oxidation of oil due to contact with the atmosphere and practically no escape of oil vapor.

b. The driving mechanism and gears shall have high efficiency and shall be quiet running with no exposed moving parts. The purifier shall be equipped with sight glasses or inspection ports to provide visual indication of the flow of both the purified oil and the separated water from the collecting pan.

c. The centrifuge of the insulating oil purifying unit shall discharge into a collecting and deaerating tank with proper float control. It shall be capable of purifying insulating oil of the characteristics mentioned in section 2 and containing 1,000 volumes of water in 1,000,000 of oil in a single pass while continuously discharging the separated water at a temperature of not over 100° F., so that the purified oil shall contain not more than 5 volumes of water in 1,000,000 of oil as determined by a high speed test tube centrifuge, and the purified oil shall have a dielectric strength of not less than 30,000 volts when tested in a standard cup with 1-inch-diameter discs spaced 0.1 inch apart.

d. The centrifuge of the lubricating oil purifying unit shall be capable of purifying lubricating oil of the characteristics stated in section 2, at a temperature of not over 140° F. at the rate guaranteed by the contractor in his bid. The capacity shall be determined by test runs in accordance with paragraphs E–1, E–1a, E–1c, and E–2 of the Bureau of Engineering, U.S. Navy Department Specification 66P2–(INT), using Navy 2190 oil at the purifying temperature of 130° F. (See also section 21.)

12. Pumps

a. Each purifying unit shall be furnished with a positive displacement feed pump and a similar type discharge pump. The pumps shall be a standard product of the contractor, or of an approved manufacturer, which has been proved reliable and satisfactory in the service intended. The pumps shall be electric-motor driven and shall operate without objectionable noise or vibration. They shall be of the helical, herringbone, or spur-gear type, or the screw type.

b. Each feed pump shall have a normal capacity of at least 10 percent greater than that of the purifying unit when operating under a maximum suction lift of 20 feet against pressure required to feed the purifier.

c. The discharge pump of the insulating oil purifying unit shall have a capacity at least equal to maximum capacity of the purifier against a discharge pressure at the outlet from the filter press of 30 pounds per square inch. The discharge pump of the lubricating oil purifier shall have a capacity at least equal to the capacity of its purifying unit against a discharge pressure at the outlet of 30 pounds per square inch.

d. Provision shall be made in each purifier to prevent the operation of its centrifuge unless the feed pump and the discharge pump are operating. Each pump shall be fitted with adequate relief bypass valves to prevent damage from excess pressures.

13. Heaters

a. The electric heaters to be furnished with each purifier shall be of the low current density type, designed so that oil will not carbonize due to high temperature at the surface of the metal surrounding the heating elements. The heaters shall have ample capacity to raise the temperature of the oil supplied when operating at the maximum capacity of the centrifugal purifier without the aid of the filter press, from 40° F., in the case of the insulating oil unit, or from 60° F., in the case of the lubricating oil unit, to the temperature which the contractor recommends for purification of the oil. Heaters

shall be suitable for operating on a 3-phase, 60-cycle, 440-volt circuit and so wired that the heater load will be equally divided, as nearly as possible, between the three phases for all positions of the temperature control switch. The heaters of the insulating oil purifying unit shall be in two or more sections, so arranged that they may be controlled manually to adjust for incoming oil temperature variations.

b. All sections of the heaters of each unit shall be piped for the oil to flow through them in series.

14. Automatic temperature control

a. In each purifying unit the temperature of the oil leaving the heater shall be automatically controlled by a double-acting, fully adjustable thermostatic switch. The thermostatic switch shall operate suitable magnetic controls which shall function to open the heater circuits when the desired temperature is exceeded and to close the heater circuits before the temperature drops below that necessary for proper purification of the oil. The heater circuits shall be interlocked with the pump motor circuits to shut off the heaters when the pumps are not being operated. Each heater shall be equipped with inlet and outlet thermometer and a drain connection.

15. Meter

a. Each oil purifying unit shall be equipped with a flowmeter, of approved manufacture, mounted in a convenient place for registering the amount of oil purified.

16. Sampling cocks

a. Sampling cocks shall be provided so that samples of dirty oil and centrifuged oil may be taken to determine the condition of the oil as it passes through each stage of purification.

17. Filter press

a. The filter press to be provided for the insulating oil purifying unit shall be of a type designed to remove fine particles of carbon or dirt which cannot be removed by the centrifuge. It shall be designed for 12- by 12-inch filter papers of standard shape and punching. A large-capacity oil-collecting pan shall be provided under the filter press, and provision shall be made for returning the oil leakage from the filter press to the centrifuge. The filter press shall be provided with pressure gages for indicating the pressure on the inlet side and the outlet side of the filter. The contractor shall furnish with the filter press 5,000 sheets of filter paper. The piping shall be so arranged that the filter may be bypassed without interfering with the normal operation of the centrifuge or the remainder of the purifying unit.

18. Piping

a. Suitable piping, fittings, oil receiver, and valves shall be furnished with each oil purifying unit so that it will operate satisfactorily as a unit. The unit shall be so arranged that it may be easily and quickly drained. Each purifying unit shall be so designed as to permit the following operations: pumping with or without the heaters; pumping with the heater and centrifuge in operation; and for the insulating oil purifying unit, pumping with the heaters and filter press in operation; and pumping with the heaters, centrifuge, and filter press in operation.

b. Each unit shall be completely piped internally to perform the specified operations so that installation by the Authority will require piping connections to one oil inlet, one oil outlet, and one water drain or discharge connection.

19. Mountings for units

a. The entire insulating oil purifying equipment, exclusive of the filter paper drier, shall be mounted upon a substantial metal base having a raised lip around the outside, with drain connections.

b. The entire lubricating oil purifying equipment shall be mounted upon a substantial metal base having a raised lip around the outside, with drain connections.

20. Tools

a. A complete set of any special tools and wrenches for the proper operation and maintenance of each purifying unit shall be furnished by the contractor. A proper device shall be furnished for handling the bowl and cleaning the centrifuge of each purifying unit. If the weight of the parts to be removed in clearing the bowl exceeds 70 pounds, a suitable hoist shall be furnished as part of the purifying unit.

21. Assembly and tests

a. Each purifying unit shall be completely assembled and tested by the contractor in his shop. The tests shall be such as are required to demonstrate that the unit will operate satisfactorily in the service intended.

b. The contractor either shall make such tests of each unit as are required to demonstrate that the unit conforms to and meets all the requirements of the specifications and provide the Authority with certified results of such tests in quadruplicate or shall provide quadruplicate certified copies of tests on units of like capacity and rating previously tested.

22. Filter paper drier

a. The filter paper drier to be furnished with the insulating oil purifying unit shall be substantially constructed of sheet steel with adequate heat insulation. The drier shall be of such type as to permit its being mounted on a stand or on brackets attached to the wall. The electric heaters shall be designed for 115-volt, single-phase, 60-cycle current and shall have manual controls for low, medium, and high heat when in operation by means of suitable switches mounted on the oven. The interior of the oven shall be provided with suspension rods from which the paper will be strung in a vertical position by means of the holes punched in the paper and so that the sheets shall be separated slightly to facilitate rapid and complete drying. Wiring shall have heat-resisting insulation and shall be concealed.

23. Painting

a. All unfinished surfaces of the equipment shall be thoroughly cleaned, filled, and painted by the contractor in accordance with his usual practice.

24. Electrical equipment

a. All electrical equipment and wiring on the purifiers shall conform to the latest requirements of the National Electrical Code, the standards of the National Electric Manufacturers' Association, and the American Institute of Electrical Engineers, except as otherwise specified.

b. All safety devices, necessary to meet these codes and standards and all other devices and equipment required for proper operation of the purifiers in the manner indicated, whether or not specifically called for, shall be furnished by the contractor.

c. The power supply will be 440 volts, 3 phase, 60 cycles. The power supply to the equipment panels will be furnished in place by the Authority. A main line safety switch, rated not less than 60 amperes, 575 volts, shall be provided with each purifier and located within easy reach from outside the purifier assembly. Protective, starting, and control equipment shall be furnished by the contractor and shall be centralized in suitable splashproof ventilated steel cabinets, neatly mounted on each purifier. The starting and protective equipment for each motor shall consist of a magnetic contactor, not less than 45-ampere enclosed rating at 440 volts, 3 phase, with thermal overload protection and undervoltage protection, a momentary contact, 600 volt, "Start-Stop" push-button station in splashproof box, and such interlocks as required to protect adequately the entire unit from trouble due to failure in the operation of any integral part. All power wiring shall consist of stranded copper conductors, 35 percent performite rubber compound, tape and braid, 1,000-volt insulation, in rigid steel conduits with threaded water tight connections, neatly arranged and firmly supported.

25. Motors

a. Motors shall be squirrel-cage, 3-phase, 440-volt, 60-cycle, constant-speed, splashproof type, with class A stator insulation and conforming to NEMA Standard MG1–1949. Each motor shall have sufficient capacity for all conditions of starting and continuous operation which the driven unit may impose,

with a temperature rise not exceeding 50° C. above an ambient temperature of 40° C.

b. All motors shall be designed for full-voltage starting, low-starting current, and normal-starting torque in accordance with NEMA Design B.

c. Stator coils and leads shall be thoroughly insulated, securely supported and braced for full-voltage start, and the completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles. A suitable conduit box shall be provided for the leads, drilled and tapped for rigid conduit.

d. The rotor core or spider shall be accurately fitted, keyed, and secured to the shaft. The squirrel-cage winding shall be of die-cast aluminum or shall be of copper or alloy bars securely attached to the end rings so as to form a mechanical and electrical bond equivalent to the solid bar.

e. Bearings shall be ball or roller type, sealed against the entrance of dust or escape of lubricant, and provided with adequate means for flushing the old lubricant when introducing new lubricant.

f. Routine tests shall be made on each motor in accordance with NEMA Standard MG1–4.29. Witness of the tests by the Authority will not be required. The contractor shall furnish the Authority seven certified copies of the results of the tests.

GUARANTEED DESIGN AND PERFORMANCE DATA

The undersigned hereby guarantees that the performance and characteristics of the equipment offered by him under this proposal will be as stated in the following tabulation.

	Item 1	*Item 2*
Complete purification unit:		
Manufacturer's name	______	______
Catalog No	______	______
Centrifuge:		
Capacity when purifying oil of the quality specified, with continuous discharge of water—		
Without press, gallons per hour	______ (Normal Navy rating)	
With press, gallons per hour	______ (Normal Navy rating)	
Capacity when purifying oil of the quality specified, without continuous discharge of water—		
Without press, gallons per hour	______	______
With press, gallons per hour	______	______
Speed of centrifuge spindle and bowl, revolutions per minute	______	______
Weight of removable centrifuge bowl, pounds	______	______
Feed pump:		
Discharge pressure, pounds per square inch	______	______
Capacity, gallons per hour	______	______
Discharge pump:		
Discharge pressure, pounds per square inch	______	______
Capacity, gallons per hour	______	
Filter press:		
Capacity, gallons per hour	______	
Pressure range, pounds per square inch	______	
Oil heaters:		
Number of units	______	______
Capacity per unit, kilowatts	______	______
Recommended temperature for the purification of the oil, degrees Fahrenheit	______	______
Pipe connections:		
Oil inlet, diameter, inches	______	______
Oil outlet, diameter, inches	______	______
Water outlet, diameter, inches	______	______
Filter paper drying oven:		
Capacity of oven, sheets	______	
Capacity of heating units, watts	______	
Approximate overall dimensions complete machine:		
Width, inches	______	______
Height, inches	______	______
Length, inches	______	______

	Item 1	Item 2
Approximate weights of complete machine:		
Operating, pounds		
Shipping, pounds		
Feed pump motor:		
Manufacturer		
Type and frame No.		
Horsepower		
Full load, revolutions per minute		
Full-load current, amperes		
Discharge pump motor:		
Manufacturer		
Type and frame No.		
Horsepower		
Full load, revolutions per minute		
Full-load current, amperes		
Centrifuge motor:		
Manufacturer		
Type and frame No.		
Horsepower		
Full load, revolutions per minute		
Full-load current, amperes		

SPECIFICATION NO. 4178—INSULATING AND LUBRICATING OIL PUMPING UNITS, FORT PATRICK HENRY PROJECT

GENERAL PROVISIONS

1. The requirement

a. The work covered by this specification comprises the furnishing and delivering of electric-motor-driven oil pumping units. All pumps shall conform to the standards of the Hydraulic Institute where applicable, except as modified by this specification.

b. The stated pressure heads are exclusive of the internal friction in the pumping units.

c. The contractor shall furnish all pumping units called for in the bid schedule, complete and ready for installation, as herein specified, and also in accordance with specifications and drawings submitted by the contractor with his bid.

d. Should any conflict arise between the specifications herein contained and those submitted by the contractor, the former shall rule in all essential requirements and, when not otherwise determined by the engineer, also in matters of detail.

e. The contractor will not be required to install any of the equipment to be furnished hereunder. The Authority will furnish the control and starting equipment for the motors of the pumping units, all electric wiring and electric conduits, all necessary supports and anchor bolts for the pumping units, and the bolts for connecting the suction and discharge piping to each of the pumping units.

2. General description

a. The insulating oil pumping units will be used for the transfer of insulating oil to transformers and oil circuit breakers about the powerhouse and switchyard. The insulating oil will have approximately the following characteristics:

Viscosity at 125° F., Saybolt Universal; 46 seconds.
Viscosity at 100° F., Saybolt Universal; 60 seconds.
Viscosity at 70° F., Saybolt Universal; 85 seconds.
Viscosity at 40° F., Saybolt Universal; 180 seconds.
Pour point; −40° F. or less.
Specific gravity; 0.9 at 60° F.

b. The normal operating temperature of the insulating oils to be pumped will vary between 70° and 105° F., but on rare occasions the temperatures of the insulating oil may vary between the extremes of 40° and 125° F.

c. The lubricating oil pumping units will be used for the transfer of lubricating oil to the main power generators and other equipment about the powerhouse. The lubricating oil will have approximately the following characteristics:

Viscosity at 125° F., Saybolt Universal; 125 seconds.
Viscosity at 100° F., Saybolt Universal; 225 seconds.
Viscosity at 70° F., Saybolt Universal; 550 seconds.
Viscosity at 60° F., Saybolt Universal; 900 seconds.
Specific gracity; 0.9 at 104° F.

d. The normal operating temperature of the lubricating oils to be pumped will vary between 70° and 105° F., but on rare occasions the temperatures of the lubricating oil may vary between the extremes of 60° and 125° F.

e. Each pumping unit shall consist of a horizontal shaft electric motor direct-connected through a flexible coupling to a rotary, positive-displacement-type pump, with all accessories necessary for satisfactory operation for a complete pumping unit.

f. The conditions of service and required operating characteristics are as follows:

	Insulating oil		Lubricating oil	
Item No.	1	2	3	4.
Service	Clean	Dirty	Clean	Dirty.
Design capacity, gallons per minute	50	50	30	30.
Design pressure, total dynamic at 70° F			45	40.
Design pressure, total dynamic at 40°F	35	20		
Location of suction*	Right	Right	Right	Right.
Location of discharge*	Left	Left	Left	Left.

*If the pumping units are of the type which have the suction and discharge openings on opposite sides of the pump head, these openings shall be oriented as listed in the above table. The location of these openings in such case is determined when facing the pump from the motor or driving end.

If the pumping units have suction and discharge openings on top of the pump head or located other than that set forth in the foregoing paragraph, the orientation of the openings stated in the above table may be disregarded.

3. The engineer

a. Work under this specification shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specification.

4. Drawings to be furnished by the contractor

a. The contractor shall furnish for approval two prints of assembly and detail drawings giving all information necessary for installation of the equipment and for demonstrating that it complies with the specifications. Drawings shall be made in a manner to give clear, permanent reproductions, ink tracings being used if necessary. Drawings shall be identified by serial numbers and descriptive titles indicating their application to the contract and shall be signed by a responsible representative of the contractor.

b. The drawings and information to be submitted by the contractor shall include:

(1) Detail and arrangement drawings of the equipment in elevation and plan, giving all important dimensions, location, and size of connections, etc.
(2) Cross-sectional drawings of the complete equipment showing all the pump and motor parts for future spare parts replacement identifications.
(3) Performance curve sheets giving efficiency, brake horsepower required, and output of the pump throughout the complete operating range from zero to maximum head.
(4) Motor outline dimension sheets.
(5) Complete installation and operating instructions.

c. The engineer will, within 10 days after receipt of drawings, cuts, or illustrations for approval, forward one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Correction."

d. Upon approval of all drawings the contractor shall furnish the Authority six additional copies of the above drawings and data.

5. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

b. Where the characteristics of any material are not explicitly specified, approved material meeting the requirements of the appropriate specifications of the American Society for Testing Materials or other recognized standard shall be employed.

c. Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish shall conform to the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications. Like parts shall be interchangeable insofar as practicable.

d. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

6. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract and shall have full facilities for unrestricted inspection of such materials or equipment.

7. Shop inspection

a. No materials or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The contractor shall keep the Engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

c. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

8. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. Flanges shall be slushed with heavy grease and protected with wooden battens.

DETAIL REQUIREMENTS

9. Pumps

a. Each pumping unit shall be a standard product of the manufacturer, of a design which has been proved reliable and satisfactory in the service intended. The design and construction of each pump shall be such that it will operate satisfactorily at full load without objectionable noise or vibration.

b. Each pump shall be a positive-displacement, rotary pump, with horizontal driving shaft direct-connected to its electric motor through an approxed flexible coupling. Each pump shall be equipped with a pressure relief or unloading device to protect the pump against excessive pressure in case of throttling in the discharge line. The relief or unloading device shall be set for a pressure which will not overload the motor when operating at full load. Relief

valves or unloading devices may be built into the pump casing or may be furnished separately for mounting in the Authority's connecting piping. Each pump shall have the capacity specified at the pressure specified and at rated speed. The specified pressure includes suction lift and friction. When filled with oil, each pump shall be self-priming for a suction lift of at least 20 feet.

c. Each pump casing shall be accurately machined and fitted. The gears or rotors shall be of heat-treated steel or special alloy iron, of suitable composition and hardness, and shall be carefully machined and fitted. The bearings of the pumps shall be properly lubricated. Each pump shall be equipped with a suitable stuffing box and packing or approved-type mechanical seals. Piping connections to the pump shall be flanged, and faced and drilled for 125-pound American Standard, or screwed with iron pipe threads.

d. Each pump and its motor shall be mounted on a rigid common base plate of cast iron or welded structural steel.

e. Before shipment, each pump shall be tested in the contractor's shop to demonstrate that it has the capacity specified at the pressure specified and that each will operate satisfactorily at the rated speed. Certified test reports shall be submitted for each pump, showing results of tests on the individual pump or on identical pumps previously tested and the viscosity of the liquid used in the tests.

10. Assembly

a. Each pumping unit with its motor shall be completely assembled on its common base plate and properly aligned. Each pumping unit shall be shipped as completely assembled as possible.

11. Motors

a. Each motor shall be squirrel cage, NEMA Design C, splashproof frame, high-starting torque, for full-voltage start and operation at 220/440 volts, 3-phase, 60 cycles.

b. The motors shall have sufficient capacity for all conditions of starting and continuous operation required by its associated pump with a temperature rise not exceeding 50° C. above an ambient temperature of 40° C. The motor speed shall not exceed 1,200 revolutions per minute for gear type and 1,800 revolutions per minute for screw type.

c. Motors shall conform to NEMA Standard MG1–1949.

d. The stator windings shall be carefully insulated and completely impregnated to withstand moisture.

e. The bearings shall be dusttight, ball or roller type, with grease seal, or adequate means shall be provided for flushing the old lubricant when introducing new lubricant and for retaining the correct amount of lubricant without dripping.

f. Routine tests shall be made on each motor in accordance with NEMA Standard MG1–4.24, except that a statement of temperature and speed, after attaining constant temperature at rated load and voltage, shall be submitted in lieu of temperature tests and speed curve. The test report shall state also that air gap, condition of bearings, and rotor balance have been inspected and are satisfactory.

g. Six copies of test report shall be furnished to the Authority. The test report shall be certified by the signature of a responsible representative of the manufacturer. Witness of test by the engineer will not be required.

12. Painting

a. All unfinished surfaces of the equipment shall be thoroughly cleaned, filled, and painted by the contractor in accordance with his usual practice.

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and size, and to have performance characteristics as good as or better than the following. In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

Pumping units

	Item No. 1	Item No. 2	Item No. 3	Item No. 4
Manufacturer				
Type of pump				
Material in gears or rotors				
Diameter of discharge outlet, inches				
Diameter of suction inlet, inches				
Theoretical displacement, gpm per 100 rpm				
Capacity at specfied total dynamic design pressure, gpm:				
35 psi at 180 ssu				
20 psi at 180 ssu				
45 psi at 550 ssu				
40 psi at 550 ssu				
Efficiency at above capacity and pressure, percent				
Power required at above capacity and pressure, bhp				
Size and type of relief valve				
Pressure at which relief valve is set, psi				
Make and type of flexible coupling				

Motors

	Item No. 1	Item No. 2	Item No. 3	Item No. 4
Motor manufacturer				
Type and frame No				
Horsepower				
Full load, rpm				
Full load, amperes				
Locked-rotor current, percent of full-load amperes				
Starting torque, percent of full-load torque				
Power factor at rated horsepower, percent				
Efficiency at rated horsepower, percent				
Bearing type (ball or roller)				

Complete pumping unit

	Item No. 1	Item No. 2	Item No. 3	Item No. 4
Overall efficiency at specified total dynamic pressure, capacity and oil temperature, percent				
Weight, pounds				

SPECIFICATION NO. 4292—SLUICE GATE OIL PUMPING UNIT, BOONE PROJECT

GENERAL PROVISIONS

1. The requirement

a. The work covered by this specification comprises furnishing and delivering of one electric-motor-driven, direct-connected, screw- or rotor-type horizontal pumping unit. The unit will be used in the hydraulic oil system for operation of the spillway gates and shall have a capacity of not less than 20 gallons per minute of oil against a total dynamic head of 1,200 pounds per square inch.

b. The contractor will not be required to install the equipment furnished under this specification.

c. The Authority will install the equipment, furnish and install all anchor bolts in accordance with bolt setting diagrams furnished by the contractor, and provide all piping connections, motor controls, wiring, and conduit.

2. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

3. Drawings to be furnished by the contractor

a. The contractor shall furnish prints of assembly and detail drawings and copies of other data in such detail as necessary for installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications. All drawings and data shall be clearly identified by serial numbers and descriptive titles, indicating their application to the contract.

b. The drawings and data submitted by the contractor shall include:

(1) Detail and arrangement drawings of the equipment in elevation and plan, giving all important dimensions, location and size of connections, and location and dimensions of anchor bolts (two prints).
(2) Cross-sectional drawings showing and identifying all the pump parts for future parts replacement identification (two prints).
(3) Motor outline and dimensions sheets (two copies).
(4) Performance curve sheets giving efficiency, brake horsepower required. and capacity of the pumps throughout the complete operating range from zero to shutoff head (two copies).
(5) Complete sets of installation and operating instructions (two copies).

c. The engineer will, within 10 days after receipt of drawings, cuts, or illustrations for approval, forward one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Correction." After approval by the engineer, the contractor shall furnish, for the Authority's records, six copies of the above.

4. Materials and workmanship

a. Materials used in the work shall be new, shall meet the requirements of an approved, recognized standard, and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

b. Workmanship shall be first class and shall be done by workmen skilled in their various trades. Tolerances, fits, and finish, when not definitely specified, shall conform with the best modern shop practices in manufacture of finished products of nature similar to those covered by these specifications.

c. Incidental fittings, fixtures, accessories and supplies shall be of approved manufacture and of standard first-grade quality. Like parts shall be interchangeable insofar as practicable.

d. All equipment shall be new and of current model and latest design, and shall be of standard, commercial, first-grade quality as to material, workmanship, and design, in accordance with the best engineering practice, and shall be such as has been proved to be suitable for the intended purpose, except that in minor details there will be permitted departures from previous designs, provided such departures are definite improvement over earlier designs.

5. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract, and they shall have full facilities for unrestricted inspection of such materials or equipment.

6. Shop inspection and material orders

a. No equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

c. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

7. Marking

a. All parts or units of assembly shall be adequately marked. Marks shall be in accordance with drawings or order lists, shall be clearly legible, and so placed as to be readily visible when the part is being erected in the field.

8. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. All finished surfaces shall be coated with an approved rust preventive. Each pumping unit shall be shipped completely assembled with its base plate.

DETAILED SPECIFICATIONS

9. Pump

a. The pump shall have a minimum capacity of 20 gallons per minute of lubricating oil against a total dynamic head of 1,200 pounds per square inch. This oil will vary in temperature from 50° to 75° F. and with the following viscosities:

Temperature, degrees Fahrenheit	*Viscosity, seconds, Saybolt Universal*
50	1,200 to 1,500
75	550 to 650

b. The rated capacity of the motor shall be sufficient to drive the pump under the lower temperature conditions against the head specified.

c. The pump shall be electric-motor-driven, screw- or rotor-type, horizontal pumping unit. The pump shall be direct-connected to its motor through a flexible coupling. All parts of the pump shall be built to withstand a momentary pressure of 2,000 pounds per square inch. The pump shall be equipped with a relief valve set at 1,400 pounds per square inch. The pump shall have hardened steel rotors or screws in a hard alloy bronze housing or hard alloy bronze rotors or screws in a hardened steel cylinder. The pump shall be so constructed that the screws or rotating elements may be removed without disconnecting the motor or suction and discharge piping. The unit shall be mounted on a cast-iron or structural bedplate. Suctions and discharge shall have flanged connections.

10. Motor

a. The motor shall conform to NEMA Standard MG1–1949 and shall be 440 volts, 3-phase, 60 cycles. Motor for a gear-type pump shall have a synchronous speed of 1,200 revolutions per minute maximum. Motor for a screw- or rotor-type pump shall have a synchronous speed of 1,800 revolutions per minute maximum. The motor shall be squirrel cage, full-voltage start, high torque, low starting current, NEMA Design B, splashproof frame.

b. The motor shall have sufficient capacity for all conditions of starting and continuous operation which the pump may impose, with a temperature rise not exceeding 50° C. above an ambient temperature of 40° C.

c. The stator frame shall be of welded steel or frame cast construction. The laminations shall be of high permeability, nonaging steel, and shall be clamped in such a manner that the stator teeth cannot vibrate or spread.

d. The stator winding shall consist of high conductivity copper with the turns carefully insulated from each other and from their supports. The coils and lead shall be securely supported and braced for full-voltage starting.

e. The rotor core or spider shall be accurately fitted and keyed to the shaft. The squirrel-cage winding shall be of indestructible die-cast aluminum or shall be of copper bars securely attached to the end rings, so as to form a mechanical and electrical bond equivalent to the solid bar.

f. The bearings shall be dusttight ball or roller type, with adequate means for flushing the old lubricant when introducing new lubricant and for retaining the correct amount of lubricant without dripping, or sealed ball or roller bearings with lubricant guaranteed for the life of the motor.

g. Strip- or cartridge-type heaters shall be provided inside the motor to prevent absorption of moisture by the motor insulation during idle periods. The heaters shall be suitable for operation at 110-volt, single-phase, 60-cycle current and shall be of adequate capacity to raise the temperature of the motor windings approximately 5° C. above ambient. The heater wiring shall preferably be terminated in the motor conduit box.

h. Complete tests shall be made on each motor in accordance with NEMA Code MG1-4.28 except that a statement of temperature and speed, after attaining constant temperature at rated load and voltage, shall be submitted in lieu of temperature tests and speed curve.

i. The test report shall also state that air gap, condition of bearings, and rotor balance have been inspected and are satisfactory.

j. Six copies of test report shall be furnished to the Authority. The test report shall be certified by signature of a responsible representative of the manufacturer. Witness of tests by the engineer will not be required.

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and size and to have performance characteristics as good as or better than the following:

Pump

Manufacturer and catalog designation ________
Type of pump ________
Full-load speed, rpm ________
Diameter of discharge outlet, inches ________
Diameter of suction inlet, inches ________
Type of pump bearings ________
Type of flexible coupling ________
Make and size relief valve ________
Material in rotors or screws ________
Material in cylinders ________
Capacity with 1,500 SSU oil against specified total head gpm ________
Efficiency at the above capacity and head, percent ________
Power required at the above capacity head, bhp ________
Capacity with 550 SSU oil against specified total head, gpm ________

Motor

Manufacturer and catalog designation ________
Type and frame No ________
Rated horsepower ________
Full load, rpm ________
Full load, amperes ________
Locked rotor, amperes ________
Power factor, at rated voltage and frequency:
  Full load ________
  Three-quarter load ________
  Half load ________
True efficiency:
  Full load ________
  Three-quarter load ________
  Half load ________
Locked-rotor torque ________
Breakdown torque ________
Bearings, type and size ________

Strip- or cartridge-type heaters

Type	______
Number and size	______
Operating current, amperes	______

Complete pumping unit

Overall efficiency at specified total head, specified capacity, and 1,500 SSU oil, percent	______
Overall efficiency at specified total head, specified capacity, and 550 SSU oil, percent	______
Total weight pump and motor assembled, pounds	______

In case of conflict between data submitted on this form and any other data included with bid, data contained hereon shall govern.

SPECIFICATION NO. 4735—VERTICAL TURBINE TYPE PUMPING UNITS FOR DRAFT TUBE UNWATERING AND STATION DRAINAGE, FORT PATRICK HENRY PROJECT

GENERAL PROVISIONS

1. The requirement

a. Under these specifications the contractor shall design, furnish, and deliver the following electric-motor-driven, vertical, turbine-type pumping units, as hereinafter specified and as shown by the contractor in data submitted with his bid:

(1) Under item 1 shall be furnished two draft tube unwatering pumps, each having a capacity of 3,000 gallons per minute against a discharge head of 55 feet.

(2) Under item 2 shall be furnished two station drainage pumps, each having a capacity of 300 gallons per minute against a discharge head of 65 feet.

b. The pumps shall be suitable for pumping strained raw river water.

c. All equipment shall be new and shall be of commercial, first-grade quality as to material and workmanship in accordance with the best engineering practice.

d. The equipment shall conform to the applicable paragraphs of the centrifugal pump section of the latest standards of the Hydraulic Institute insofar as applicable, except as herein modified.

e. The stated heads are exclusive of the internal friction in the pumping units.

2. General arrangement

a. All pumps shall be arranged for above-the-floor discharge.

b. The required characteristics and limiting conditions for the construction of the units are as follows:

	Item No. 1	Item No. 2
Number of units	2	2
Design capacity, gpm	3, 000	300
Design head, TDH, feet	55	65
Maximum head, TDH, feet [1]	90	80
Minimum head, TDH, feet	20	30
Pump speed, maximum, rpm	1, 200	1, 800
Elevation, discharge centerline	1, 209. 0	1, 208. 5
Maximum distance between bottom of motor base plate and discharge centerline, inches	24	18
Elevation, bottom of well	1, 149. 0	1, 158. 5
Elevation, maximum water level in well [2]	1, 194. 0	1, 169. 5
Approximate elevation, minimum water level in well	1, 152. 0	1, 160. 5
Elevation, lower end of suction strainer	1, 150. 0	1, 159. 0

[1] The shutoff head shall be materially greater than the indicated maximum head.
[2] The item 1 pumps will normally be started only when water in the well is at maximum elevation.

3. The engineer

a. Work under these specifications shall be subject to the approval of the Chief Engineer of the Authority, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder, and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

4. Drawings and data to be furnished by the contractor

a. Within 30 days after notice of award of contract, the contractor shall furnish two copies of assembly and detail drawings, instructions, and cuts of the work in such number and detail as necessary for installation, operation, and maintenance of the equipment, and for demonstrating that it complies with the requirements of the specifications.

b. Such drawings shall include but shall not be limited to the following:

(1) Outline, plan, and elevation of units showing all principal dimensions and location of anchor bolts.
(2) Complete installation and operating instructions.
(3) Characteristic curves of the pumps.
(4) Cross-section drawings of the pumps showing all parts and parts lists for future parts replacement.
(5) Motor outline prints.

c. The engineer will, within approximately 10 days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Approved," "Approved with Corrections as Noted," or "Returned for Correction."

d. Upon approval of all data the contractor shall furnish the Authority seven complete sets of prints of all drawings approved by the engineer, including all corrections and revisions made up to the time of completion of the work.

e. Approval by the engineer shall not be held to relieve the contractor of the responsibility for the correctness of the drawings furnished by him.

5. Materials and workmanship

a. Materials used in the work shall be new and shall be of kind, composition, and physical properties best adapted to their several purposes in accordance with best engineering practice.

b. Approved material meeting the requirements of the latest ASME or ASTM standards shall be employed unless otherwise specified.

c. Materials shall at all times be kept clean and protected from the weather and shall be free from excessive scale and rust. Workmanship shall be first class and shall be done by workmen skilled in their various trades.

d. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and of standard first-grade quality.

6. Work to be done and materials to be furnished by the Authority and others

a. Foundations and anchor bolts.
b. All piping and valves except as otherwise specified.
c. Field paintings.
d. Electric wiring.
e. Bolts, nuts, and gaskets for flanges.
f. Starting equipment.
g. Installation of the equipment.

7. Access to work

a. The engineer and his assistants and other agents of the Authority shall at all times have access to all places of manufacture where equipment or materials are being made or prepared for use under this contract and shall have full facilities for unrestricted inspection of such materials or equipment.

b. The contractor shall, if required, furnish suitable office space, equipment, and telephone facilities to enable the Authority's representative to perform his official duties.

8. Shop inspection and materials orders

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected unless the engineer authorizes inspection to be made elsewhere.

b. The contractor shall keep the engineer informed in advance of the time of starting and of the progress of the work in its various stages so that arrangements can be made for inspection.

c. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specifications and shall not prevent subsequent rejection if such material or equipment is later found to be defective.

9. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. All finished surfaces shall be coated or otherwise protected with an approved rust preventive. All exposed flanged faces shall be adequately protected. All screwed connections shall be plugged.

10. Shop assembly and tests

a. Each pump shall sustain a hydraulic pressure, in the shop, of not less than 150 percent of the shutoff head of the pump, without any indication of weakness or leakage.

b. Six certified test reports of the pumps shall be furnished for approval prior to shipment of the units. These test reports shall include complete characteristic curves of the pumps from shutoff to maximum flow. These curves may either be derived from the pumps furnished under this contract or on identical pumps tested previously.

c. The approval of the factory tests shall in no way relieve the contractor from his obligations under these specifications.

11. Painting

a. The pumping units shall be painted in accordance with the contractor's standard practice.

DETAILED REQUIREMENTS

12. Pumps—General

a. The pumping units shall be of the vertical, turbine type and shall conform to applicable paragraphs of the "Standards of the Hydraulic Institute," section E, for that type of pump, except as herein modified. It shall be a standard product of a manufacturer regularly engaged in the production of such pumping units and shall be of a design and construction that has been proved reliable and satisfactory for continuous operation. The unit shall be designed so as to be readily assembled or dismantled. The design and workmanship shall be such that the pumping unit will operate satisfactorily for the intended service, without undue wear on any parts and without objectionable vibration. An approved method will be provided for disengaging the motor from the pump shaft if the motor be operated in the reverse direction from normal.

b. The operating characteristics of each pump and the rated capacity of its motor shall be such that the motor shall not exceed its rated temperature rise or name plate horsepower capacity under any head condition from the minimum heads specified to shutoff.

13. Bowls and impellers

a. The pump bowls shall be made of close-grained iron in flanged sections. All water passages shall be accurately cast and smoothly finished.

b. Impellers shall be made of bronze and shall be fastened to the shaft with stainless steel keys, or by other approved method, smoothly finished and properly balanced.

14. Shafts and bearings

a. Impeller shafts shall be made of stainless steel or other approved corrosion-resisting material, rolled or forged, and ground. Line shafts shall be made of ground, rolled or forged, open-hearth steel shafting. Shaft couplings shall be screwed and made of stainless steel or bronze. Line shafts shall be properly balanced.

b. Line shafting shall be made in sections of convenient length for assembling and dismantling the pumping unit. A nut shall be provided at the top of the line shaft to adjust the impeller vertical clearances.

c. A thrust bearing shall be furnished in the motor which shall be ball or roller type and shall be of ample capacity for the maximum thrust load of the pump and the total weight of all revolving parts of the pumping unit.

d. The pumps shall be self-lubricated by the water being pumped.

e. Line shaft bearings shall be rubber or phenolic plastic. Bearings shall be so spaced that the critical speed of the shaft shall be sufficiently greater than the pump speed to prevent vibration.

f. Stainless steel or monel metal sleeves shall be securely fastened to the line shaft at points of bearing.

g. Guiding spiders of bronze or other approved corrosion-resisting material shall be provided for supporting the line shaft bearings. Spiders shall be of streamlined design and shall be fitted into machined recesses in the discharge column.

h. The bearings in the pump bowls shall be water-lubricated and may be either bronze sleeve or rubber.

i. The bottom bearing of the pumps may either be a grease-packed bronze sleeve bearing or a water-lubricated rubber bearing.

15. Discharge column and head

a. The discharge column of the pumping unit shall support the pump assembly from the motor base. The column shall be black steel pipe or tubing of adequate strength for the service but in no case lighter than standard-weight pipe if 12 inches in diameter or less, or not less than three-eighth inch thick if greater than 12 inches in diameter. All joints in discharge columns 6 inches in diameter and larger shall be flanged. Joints in columns smaller than 6 inches may be either flanged or screwed.

b. The motor base shall be of cast iron with skirted base and discharge head integral with the base.

c. The discharge head shall have a flanged discharge connection, drilled ASA 125 pounds standard. An adequate grease-lubricated stuffing box, or other approved means, shall be provided around the line shaft where it passes through the discharge elbow for preventing leakage during operating conditions.

16. Lubrication

a. All bearings below the stuffing box shall be lubricated by the flow of water past them, except the bottom bearing which may be grease-packed. Pumps requiring prelubrication will not be considered.

b. The thrust bearing shall be oil-lubricated, dusttight, and watertight and have adequate means of retaining the correct amount of lubricant without dripping and shall be provided with a sight glass or other means of indicating the level of the lubricant.

c. A suitable grease cup shall be provided for grease lubrication of the stuffing box on the line shaft where it leaves the discharge column.

17. Strainer

a. The pumps shall be provided with a substantial cast-iron strainer of the basket type, in which the total net area of the openings shall be at least twice the nominal suction size of the pump.

18. Motor

a. Motors shall conform to NEMA Standard MG1–1949.

b. The motor shall be vertical axis, hollow-shaft type, squirrel cage, 440 volts, 3-phase, 60 cycles, normal torque, low-starting current, dripproof frame, and full-voltage start, with synchronous speed not exceeding that tabulated in section 2.

c. Each motor shall have adequate capacity and operating characteristics for all conditions of starting and continuous operation which the pump to which it is connected may impose, with a temperature rise not exceeding 40° C. above an ambient temperature of 40° C.

d. Stator coils and leads shall be thoroughly insulated, securely supported and braced for full-voltage start, and the completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles. A suitable conduit box shall be provided for the leads.

e. The rotor core or spider shall be of one-piece construction, aluminum or copper, or composed of copper bars so brazed or otherwise attached to the end rings as to form a mechanical and electrical bond equivalent to the solid bar.

f. The guide and thrust bearings shall be dusttight ball or roller type, with adequate provision for lubrication and means for retaining the correct amount of lubricant without dripping, and provided with suitable means for flushing the old lubricant when introducing new lubricant. Each thrust bearing shall be capable of sustaining the maximum thrust load of its pump and the total weight of all revolving parts of the pumping unit.

g. Routine tests shall be made on each motor in accordance with NEMA Code MG1–4.24, except that a statement of temperature and speed, after attaining constant temperature at rated load and voltage, for a duplicate design motor shall be included. The test report shall also state that air gap, condition of bearings, and rotor balance have been inspected and are satisfactory. Witness of tests by the Engineer will not be required.

h. An automatic releasing clutch shall be built into the motor which shall protect the motor and line shaft in case the motor is operated in the opposite direction.

DESIGN AND PERFORMANCE DATA

(See page 920)

498128 O—60——60

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and size, and to have performance characteristics as good as or better than the following:

Pumps

	Item No. 1	Item No. 2
Manufacturer		
Type of pump		
Full-load speed, rpm		
Size of discharge outlet, inches		
Distance from center line of outlet to bottom of base plate, inches		
Type of impeller		
Number of stages		
Size of discharge column inches		
Thickness of column walls, inches		
Discharge in gallons per minute at specified total dynamic head		
Shutoff head, feet		
Maximum power required at any head between the minimum specified and shutoff, bhp		
Will prelubrication be required		

Motors

Manufacturer		
Type and frame number		
Rated horsepower		
Full load, rpm		
Full load, amperes		
Locked rotor, amperes		
Power factor, at rated voltage and frequency:		
Full load		
Three-quarter load		
Half load		
Efficiency at rated voltage and frequency:		
Full load		
Three-quarter load		
Half load		
Locked rotor torque		
Guide bearings, type and size		
Thrust bearing, type and capacity		

Complete pumping units

Overall efficiency at total dynamic design head and design capacity specified in section 2, percent		
Weight of one complete units, pounds		

In case of conflict between data submitted on this form and any other data included with the bid, data contained hereon shall govern.

APPENDIX C

HEATING, VENTILATING, AND AIR-CONDITIONING EQUIPMENT BID SCHEDULES, EQUIPMENT DATA, AND SPECIFICATIONS

Appendix C includes typical bid schedules, equipment data, and specifications for the procurement of heating, ventilating, and air-conditioning equipment and accessories. General clauses of the invitation to bid document are omitted. This appendix includes:

Typical drawings utilized for procurement of ventilating fans, filters, cooling coils, electric heaters, wire guards, dampers, and louvers are shown in plates 41 and 42, pages 604 and 610.

BID SCHEDULE, DESIGN AND PERFORMANCE DATA AND SPECIFICATION NO. 00—TYPICAL VENTILATING FAN

(Reference drawings not included in this report)

BID SCHEDULE

Item	Articles or services	Quantity	Unit
	SCHEDULE I		
1	Centrifugal fan, mark 47N751-1 Point of manufacture ____ (Street) (City) (State)	2	Each.
2	Centrifugal fan, mark 47N751-2 Point of manufacture ____ (Street) (City) (State)	3	Do.
3	Centrifugal fan, mark 47N751-3 Point of manufacture ____ (Street) (City) (State)	2	Do.
4	Centrifugal fan, mark 47N751-4 Point of manufacture ____ (Street) (City) (State)	1	Only.
	SCHEDULE II		
5	Vaneaxial fan, mark 47N751-20 Point of manufacture ____ (Street) (City) (State)	2	Each.
6	Vaneaxial fan, mark 47N751-21 Point of manufacture ____ (Street) (City) (State)	3	Do.
	SCHEDULE III		
7	Propeller fan, mark 47N751-25 Point of manufacture ____ (Street) (City) (State)	1	Only.
	SCHEDULE IV		
8	Roof ventilator, mark 47N751-30 Point of manufacture ____ (Street) (City) (State)	2	Each.
9	Roof ventilator, mark 47N751-31 Point of manufacture ____ (Street) (City) (State)	4	Do.

DESIGN AND PERFORMANCE DATA

The undersigned bidder proposes to furnish equipment guaranteed to be in accordance with the specifications and to be of the manufacture, type, and size and to have performance characteristics as good as or better than the following:

ITEM 1. CENTRIFUGAL FAN, MARK 47N751-1

Fan

Manufacturer ____________ Catalog designation ____________
Capacity ____________ cfm against ____________ static pressure
Rpm ____________ Bhp ____________ at specified performance
Outlet velocity ____________ fpm, tip speed ____________ fpm
Bearings, type, and size ____________
Gage sides and scroll ____________
Net weight ____________
Does fan carry NAFM Certified Rating Seal? ____________
Other method of guaranteeing performance ____________

Motor

Manufacturer ____________ Type and frame No. ____________
Horsepower ____________, rpm ____________ full load, amperes ____________
Starting current, amperes ____________
Net weight ____________

Drive

Manufacturer ____________
Number of belts ____________, section ____________, rating ____________ hp per belt __
Fan pulley, pitch diameter ____________
Motor pulley, pitch diameter ____________

Outlet damper

Manufacturer ____________ Catalog designation ____________
Number of leaves ____________ Gage of leaves ____________

Damper motor

Manufacturer ____________ Catalog designation ____________

Inlet guards

Manufacturer ____________

Resilient base

Manufacturer ____________ Resilient elements, material ____________

ITEM 2. CENTRIFUGAL FAN, MARK 47N751-2

Fan

Manufacturer ____________ Catalog designation ____________
Capacity ____________ cfm against ____________ static pressure
Rpm ____________ Bhp ____________ at specified performance
Outlet velocity ____________ fpm, tip speed ____________ fpm
Bearings, type, and size ____________
Gage sides and scroll ____________
Net weight ____________
Does fan carry NAFM Certified Rating Seal? ____________
Other method of guaranteeing performance ____________

Motor

Manufacturer ____________ Type and frame No. ____________
Horsepower ____________, rpm ____________ full load, amperes ____________
Starting current, amperes ____________
Net weight ____________

Drive

Manufacturer ____________
Number of belts ____________, section ____________, rating ____________ hp per belt
Fan pulley, pitch diameter ____________
Motor pulley, pitch diameter ____________

Outlet Damper

Manufacturer ____________ Catalog designation ____________
Number of leaves ____________ Gage of leaves ____________

Damper motor
Manufacturer__________ Catalog designation__________

Inlet guards
Manufacturer__________

Resilient base
Manufacturer__________Resilient elements, material__________

ITEM 3 CENTRIFUGAL FAN, MARK 47N751–3

Fan
Manufacturer__________Catalog designation__________
Capacity__________cfm against__________static pressure
Rpm__________Bhp__________at specified performance
Outlet velocity__________fpm, tip speed__________fpm
Bearings, type, and size__________
Gage sides and scroll__________
Net weight__________
Does fan carry NAFM Certified Rating Seal?__________
Other method of guaranteeing performance__________

Motor
Manufacturer__________Type and frame No.__________
Horsepower__________, rpm__________full load, amperes__________
Starting current, amperes__________
Net weight__________

ITEM 4. CENTRIFUGAL FAN, MARK 47N751–4

Fan
Manufacturer __________ Catalog designation__________
Capacity __________ cfm against __________ static pressure
Rpm __________ Bhp __________ at specified performance
Outlet velocity__________ fpm, tip speed __________ fpm
Bearings, type, and size__________
Gage sides and scroll __________
Net weight __________
Does fan carry NAFM Certified Rating Seal? __________
Other method of guaranteeing performance __________

Motor
Manufacturer __________ Type and frame No. __________
Horsepower __________ rpm __________ full load, amperes __________
Starting current, amperes __________
Net weight __________

ITEM 5. VANEAXIAL FAN, MARK 47N751–20

Fan
Manufacturer __________ Catalog designation __________
Capacity __________ cfm against __________ static pressure
Bhp __________ at specified performance
Outlet velocity __________ fpm, diameter of fan wheel __________
Is capacity certified in accordance with the latest applicable NAFM test codes?
____

Motor
Manufacturer __________ Type and frame No. __________
Horsepower __________ rpm __________ full load, amperes __________
Starting current, amperes __________

Resilient mounting
Manufacturer __________ Resilient elements, material __________

Assembly
Overall length __________ Gross weight __________

ITEM 6. VANEAXIAL FAN, MARK 47N751-21

Fan

Manufacturer ______________________ Catalog designation __________
Capacity ______________ cfm against __________________ static pressure
Bhp ____________________________________ at specified performance
Outlet velocity __________ fpm, diameter of fan wheel ________________
Is capacity certified in accordance with the latest applicable NAFM test codes?
____

Motor

Manufacturer ______________________ Type and frame No. __________
Horsepower ____________ rpm _________ full load, amperes ___________
Starting current, amperes ____

Inlet bell

Manufacturer ____

Resilient mounting

Manufacturer ______________ Resilient elements, material _____________

Assembly

Overall length ______________ Gross weight ___________________________

ITEM 7. PROPELLER FAN, MARK 47N751-25

Fan

Manufacturer ______________________ Catalog designation __________
Capacity ______________ cfm against __________________ static pressure
Rpm __________________ Bhp ________________ at specified performance
Does fan carry PFMA Certified Rating Label? ___________________________

Motor

Manufacturer ______________________ Type and frame No. __________
Horsepower ____
Rpm at full load ____________ full load, amperes _____________________
Starting current, amperes ____

Inlet guard

Manufacturer ______________________ Size and gage of mesh ________

Assembly

Gross weight (including mounting plate) ______________________________

ITEM 8. ROOF VENTILATOR, MARK 47N751-30

Fan

Manufacturer ______________________ Catalog designation __________
Capacity______________ cfm against __________________ static pressure
Bhp____________________________________ at specified performance

Motor

Manufacturer ______________________ Type and frame No. __________
Horsepower ____________ rpm _________ full load, amperes ___________
Starting current, amperes ____

Assembly

Overall diameter ____
Overall height ____
Size of ventilator base ____
Net weight ____

ITEM 9. ROOF VENTILATOR, MARK 47N751-31

Fan

Manufacturer ______________________ Catalog designation __________
Capacity ______________________ cfm against __________ static pressure
Bhp ____________________________________ at specified performance

Motor

Manufacturer ______________________ Type and frame No. __________
Horsepower ____________ rpm _________ full load, amperes ___________
Starting current, amperes ____

Assembly
Overall diameter ______
Overall height ______
Size of ventilator base ______
Net weight ______

SPECIFICATION NO. 00

GENERAL PROVISIONS

1. The requirement

a. The work covered by this specification comprises the furnishing, fabricating, assembling, and delivering of centrifugal, vaneaxial, and propeller fans and roof ventilators, complete with motors and accessories, and for the heating, ventilating, and air-conditioning systems.
b. The contractor shall furnish such items of the bid schedule as have been included in the contract.
c. The work shall be complete as herein specified and as shown or called for on TVA's drawing, and also in accordance with the specifications and drawings submitted by the contractor.
d. Should any conflict arise between the specifications or drawing of TVA and those submitted by the contractor, the former shall rule in all essential requirements and, when not otherwise determined by the engineer, also in matters of detail.
e. TVA will furnish materials and do work as follows:

(1) Install the equipment furnished by the contractor.
(2) Construct all masonry foundations and furnish and set all anchor bolts which are embedded in concrete or other masonry.
(3) Furnish and install all sheet metal ducts and make all connections between the ducts and the fans.
(4) Furnish and install all electric wiring, conduit, motor-starting switches, safety switches, and electric-control devices and make all electric connections to the motors.

2. The engineer

a. Work under this specification shall be subject to the approval of the Chief Engineer of TVA, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specifications.

3. TVA's drawing

a. The work covered by this specification is shown and detailed on the accompanying drawing No. 47N751 entitled "Mechanical, Heating and Ventilating Fans." This drawing shall be referred to in this specification as "the drawing."
b. TVA will be responsible for the correctness of its design, but the contractor shall carefully check all dimensions and quantities on the drawing and schedules furnished by TVA and shall advise the engineer of any errors or omissions discovered.

4. Drawings and data to be furnished by the contractor

a. The contractor shall furnish two copies of assembly and detail drawings, cuts, and data in such detail as necessary for installation, operation, and maintenance of the equipment and for demonstrating that it complies with the requirements of the specification. All drawings shall be subject to the approval of the engineer and shall be clearly identified by serial numbers and descriptive titles indicating their application to the contract.
b. The engineer will, within 10 days after receipt of drawings, cuts, and data for approval, forward one copy to the contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."
c. The contractor shall make necessary corrections and revisions on drawings "Approved with Correction as Noted" and on drawings "Returned for Correction" and shall resubmit them for approval. Time required for such revision and resubmission will not entitle the contractor to any extension of

time, but the engineer will examine and return such prints as promptly as possible.

d. Approval by the engineer shall not relieve the contractor of the responsibility for the correctness of the drawings furnished by him nor for their compliance with the specification.

e. The drawings and data shall include:

(1) Complete assembly drawings, including foundation and bolt setting diagrams and drawings.
(2) Outline drawings of the principal pieces of equipment showing major dimensions.
(3) Electric motor data sheets showing outlines, principal dimensions, location of anchor bolts and conduit connection, and nameplate rating.
(4) General and detail assembly drawings, catalog pages, printed cuts or dimension sheets of accessory equipment, and control devices.
(5) Guaranteed performance data for each fan, in graphic form, including all performance characteristics throughout the full range from free delivery to no delivery. Tests for the determination of these data shall have been conducted in accordance with the latest edition of the Standard Test Code of the National Association of Fan Manufacturers or Propeller Fan Manufacturers Association.

f. Cuts, catalog pages, or other data showing more than one piece of equipment or equipment having variable dimensions, characteristics, or functions shall be so marked as to clearly identify the equipment to be furnished.

g. Upon final approval of all drawings the contractor shall furnish, for the permanent files of TVA, six copies of each drawing and data sheet.

5. Equipment

a. All equipment shall be new and of latest design, shall be first-grade quality as to material and workmanship, and shall be such as has been proved to be suitable for the intended purpose.

b. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and standard first-grade quality.

6. Access to work

a. The engineer and his assistants and other agents of TVA shall at all times have access to all places where work is being done under this contract, and they shall have full facilities for unrestricted inspection of such work.

7. Shop inspection

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specification, and it shall not prevent subsequent rejections if such material or equipment is later found to be defective.

8. Marking

a. All parts or units of assembly shall be adequately marked. Marks shall be in accordance with drawings or order lists, shall be clearly legible, and so placed as to be readily visible when the part is being erected in the field.

b. Connecting parts assembled in the shop shall, before dismantling for shipment, be match-marked to facilitate erection in the field. The location of the match marks shall be clearly indicated.

9. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit, and he shall be responsible for and make good any and all damage due to improper preparation or loading for shipment. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. All finished surfaces shall be coated with an approved rust preventive.

10. Centrifugal fans

a. The fans, marks 47N751-1 through 47N751-4, shall be fully housed centrifugal fans of standard design. Each fan shall be complete with motor and accessory equipment, including all necessary keys, anchors, bolts (except anchor bolts embedded in masonry), and all other devices needed for assembling, erecting, and securing the fans and other equipment in place. Drives, resilient bases, and inlet guards shall be provided as shown or called for on the drawing.

b. Each fan shall have the required capacity when operating within the limits of outlet velocity, rotative speed, and against the static pressure shown on the drawing.

c. Each fan shall have width, direction of discharge and rotation, arrangement of inlet, bearings, and drive as shown on the drawing. Each fan shall conform to the dimensional limitations, if any, shown on the drawing. Each fan shall have inlet ring and discharge adapted for connection to TVA's sheet-metal duct, or canvas connections, without requiring any additional or supplemental lip or extension.

d. Each fan shall be constructed with steel sheet housing of gage not lighter than shown on the drawing, except that housing for fan, mark 47N751-4, may be cast iron or aluminum. The housing shall be reinforced with structural steel or cast iron as required for rigidity, for elimination of breathing and buckling, and for the support of the bearings.

e. The fan wheel shall be sturdily constructed of steel or steel and cast iron with blades of form and arrangement as called for on the drawings. The wheel shall be provided with an approved backplate or spider and adequate means for securing the wheel to the shaft. The shaft shall be of steel carefully machined, true, and of ample strength and stiffness to prevent distortion, whipping, or vibration where the fan is operating at speed equal to 150 percent of the specified speed under any condition of static pressure from free delivery to static no delivery. Proper provision shall be made for attaching and securing the fan wheel and the driving device in place. The wheel and shaft shall be carefully fitted and assembled together, and the assembly shall be statically and dynamically balanced.

f. Fans, mark 47N751-3, shall be direct-connected and shall have two bearings as shown on the drawing corresponding to NAFM No. 7.

g. Fans, marks 47N751-1 and 47N751-2, shall be belt-driven and shall have two bearings as shown on the drawing corresponding to NAFM arrangement No. 3.

h. Fan, mark 47N751-4, shall be direct-connected, with the fan wheel mounted directly on the motor shaft as shown on the drawing corresponding to NAFM arrangement No. 4. A suitable pedestal or bracket shall be provided for the support of the motor and shall be attached to the housing.

i. Fans, mark 47N751-1, shall be furnished with a split housing with the assembly joint horizontal at the shaft centerline. These fans are to be shipped knocked down to permit the fan to be assembled at the installation.

j. Fan, mark 47N751-4, shall be protected against dilute sulfurous acid fumes by a suitable protective coating which shall be applied to the fan wheel, inside the housing, and that part of the shaft which is exposed to the gases passing through the fan. The coating shall be erosion- and corrosion-resistant, securely bonded to the base metal, and shall be equal to "Heresite," seven coats baked on.

k. Bearings shall be roller, ball or sleeve type, bronze or babbitt-lined as the contractor has stated in his bid. Bearings shall be self-aligning, substantially constructed, and shall have adequate provisions for lubrication. Sleeve bearings shall be ring oiling with ample oil reservoir and oil level gage. Ball and roller bearings shall be grease-lubricated, and each bearing shall be provided with an approved pressure-type grease fitting. Each bearing mounted in a fan inlet shall have an extension to the oil or grease feed so arranged that the bearing may be conveniently lubricated from outside any duct connection that may be made to the fan inlet. The oil level gauge of each oil-lubricated bearing shall be extended as necessary to clear duct connections to the fan inlet.

l. The capacity and characteristics of each fan shall be as published in the manufacturer's catalog and shall be as determined by tests made in accordance with the Standard Test Code as sponsored by the American Society of Heating and Ventilating Engineers and the Engineering Committee of the National Association of Fan Manufacturers. Guarantee of the above requirements may be made either by the use of the NAFM label or photostat copies

of certified tests of fan of size quoted or as covered by paragraph 17 of the Standard Test Code, made in conformity with above code by a certified independent laboratory, to be furnished with bid.

11. Drives

a. Belted drives shall be of the multiple V-belt type. Each drive shall consist of a cast-iron fan pulley, cast-iron motor pulley, and endless rubber and fabric V-belts, the number of belts being not fewer than 175 percent of the number required, according to the manufacturer's published ratings for the motor rating, and in no case fewer than two belts. Individual belts shall not be smaller in section than $^{21}/_{32}$ by $^{7}/_{16}$.

b. Pulleys shall be accurately proportioned so that the several fans will be driven at the correct speed, grooved for the proper number of V-belts, as specified above, statically and dynamically balanced and bored, fitted, and keyed to their respective shafts. No pulley shall be smaller than 5½-inch pitch diameter.

c. Flexible couplings shall be of approved type. Each coupling shall be ruggedly constructed and adequate for its application. It shall be carefully fitted and secured to the fan and motor shaft.

d. A removable metal guard of substantial construction shall be furnished for each flexible coupling. The guard shall adequately protect the operators and others from contact with the coupling.

12. Inlet guards

a. Inlet guards where called for on the drawing shall be substantially constructed of heavy wire screen firmly held in a steel frame. The screen shall be square or diamond mesh, woven from steel wire not lighter than No. 10 American wire gage, spaced not more than 1½ inches center to center each way or ¾-inch diamond mesh expanded metal of No. 14 USS gage sheet steel. The frame shall be of steel, of adequate strength, carefully fitted to the fan inlet, and shall be provided with suitable slips or other approved devices for attaching to the fan housing.

b. Provisions shall be made for access to the fan or motor bearings or other parts which may require lubrication or maintenance.

13. Outlet dampers

a. Fans, marks 47N751-1 and 47N751-2, shall have an automatically operated damper mounted on the discharge. The dampers shall be of heavy-duty construction, horizontally pivoted, multileaf type, complete in one frame with leaves, stops, bearings, linkages, counterweights or springs, and automatic operating devices as required.

b. Each damper frame shall be of extra-heavy construction, substantially and neatly fabricated, and shall be braced as necessary to provide adequate rigidity and to offer a minimum of resistance to air flow.

c. Each damper shall be mounted on its fan discharge and shall have provisions for connecting to the TVA's sheet-metal discharge duct.

d. The individual leaves shall be fabricated from soft iron or steel sheet not lighter than No. 14 USS gage for single-thickness leaves or its equivalent in double-thickness or diamond construction. The leaves shall be reinforced by forming or crimping or by other approved means of increasing strength and rigidity. Each leaf shall be securely mounted on a shaft or on trunnions and shall be provided at each end with substantial ball bearings of approved design rigidly mounted on the damper frame.

e. The individual leaves of each damper shall be linked together so that all leaves will operate together as a unit. Linkages shall be carefully designed and accurately constructed with bronze-bushed pin or equal connections and shall have all necessary provisions to ensure smooth operation and to avoid rattling or free motion of the damper leaves.

14. Damper motors

a. Electrically operated damper motor shall be furnished and mounted on the fan housing or structural members, designed for operating the damper through a suitable linkage. The motor shall be designed for 115-volt, single-phase, 60-cycle operation, 2-position, spring return, arranged to have outlet damper open when energized. The motor shall be of ample capacity to operate the damper and shall be equal to Minneapolis-Honeywell Regulator Co. type M405B.

b. Suitable brackets and linkage shall be provided for mounting the motor on the fan housing and for connecting to the operating mechanism of the damper.

15. Resilient bases

a. Resilient bases shall be designed to support both fan and motor in such manner as to effectively dampen vibration and reduce its transmission into the structure. Each base shall be of steel and rubber, or steel and steel spring construction, carefully designed for the loading and frequency of vibration to which it will be subjected. It shall be completely fabricated and assembled in one piece with provisions for mounting the fan and motor in their proper relative positions on it and for anchoring it to the foundation.

16. Vaneaxial fans

a. The fans, marks 47N751–20 and 47N751–21, shall be of the vaneaxial type as defined by the National Association of Fan Manufacturers. Each fan shall have the required capacity when operating within the limits of outlet velocity, rotative speed, and against the static pressure shown on the drawing.

b. The vaneaxial fans shall be direct-connected as called for on the drawing. They shall be furnished complete with electric motor, housing ring, guide vanes, and accessory equipment as shown or called for on the drawing.

c. Each fan wheel shall be multiblade type with adequate hub diameter, with nonoverloading characteristics, designed for high operating efficiency against the required head. The wheel shall be statically and dynamically balanced, and shall be mounted on and securely attached to the motor shaft, or on shafting adequately supported by pillow block-type bearing.

d. Each ring shall be of rigid construction with guide vanes to direct the flow of air through the fan in the most efficient manner. Provisions shall be made for supporting the motor and fan wheel either on the vanes or on suitable separate supports. The ring shall have hangers, brackets, or other suitable provisions as shown on the drawing for supporting the fan from TVA's structure.

e. The bearings shall be of the lifetime-lubricated type or provided with suitable means for lubrication, and the lubricant feed shall be extended in such manner that the fan may be conveniently lubricated from outside the ring without requiring the dismantling of any part of the fan or connecting ducts.

f. The vaneaxial fans shall be designed for vertical air flow. The motors and bearings shall be of a type suitable for this service.

g. Matching angle rings shall be furnished for fans as shown or called for on the drawing.

h. Resilient mountings shall be provided for each fan as shown or called for on the drawing. The mounting shall be of steel and rubber or steel and steel spring construction, carefully designed for the loading and frequency of vibration to which it will be subjected.

i. Inlet screens shall be furnished for vaneaxial fans, as called for on the drawing. The screens shall be of standard design with the manufacturer and of ample weight and strength to adequately protect workmen and maintenance men from the rotating blades.

j. The fans, mark 47N751–20, shall be designed for installation in duct runs. Fans, mark 47N751–21, shall be designed to pick up air from a free area and discharge into a duct system and shall be furnished complete with inlet bell to improve air entry conditions.

k. The capacity and characteristics of each fan shall be as published in the manufacturer's catalog and guaranteed and certified by the contractor to be correct as determined by tests made in accordance with the applicable plates of the Standard Test Code as sponsored by the American Society of Heating and Ventilating Engineers and the Engineering Committee of the National Association of Fan Manufacturers.

17. Propeller fans

a. The fan, mark 47N751–25, shall be direct-connected, motor-driven propeller fan, complete with motor, inlet guard, and mounting plate. The fan shall have capacity and pressure characteristics as called for on the drawing. The capacity and characteristics shall be as published in the manufacturer's catalog and shall be as determined by tests conducted in accordance with the Standard Test Code as adopted by the American Society of Heating and Ventilating.

Guarantee of the above requirements shall be made by the use of the Propeller Fan Manufacturer's Association Certified Rating Label on the fan.

b. The fan wheel shall be quiet-operating, accurately balanced, and securely fastened to the motor shaft. The motor shall be single speed, having voltage, phase, and frequency as called for on the drawing.

c. Suitable wire guard shall be provided, essentially as shown on the drawing, in accordance with the manufacturer's standards.

d. A steel mounting plate, cut from ¼-inch steel plate, shall be furnished for the fan, cut accurately to outside dimensions as called for on the drawing. Each plate shall be cut and drilled to receive the fan being furnished.

18. Roof ventilators

a. The roof ventilators, marks 47N751-30 and 47N751-31, shall be motor-driven power ventilators, weatherproof, free of exposed obstructing bracing, round housing, square mounting frame, round die-formed mushroom-shaped canopy, rigidly constructed of heavy-gage sheet steel and rolled shapes, of capacity and operating characteristics as shown or called for on the drawing. The roof ventilators shall be designed for mounting on square curbs furnished by TVA. Each fan shall be slow speed and quiet operating and may be either belt driven or direct driven.

b. TVA will furnish and install motor-driven dampers in the opening formed by the curbing. The damper motor will be on the top side of the damper, and each roof ventilator must be hinged near the base to allow full access to the damper motor for servicing and maintenance. The canopy or upper portion must also be hinged to allow full access to the roof ventilator motor.

c. The roof ventilators, mark 47N751-30, shall be arranged for exhausting air from a space below, and the roof ventilators, mark 47N751-31, shall be arranged for blowing air into a space below.

d. All roof ventilators shall be furnished with a bird screen with mesh not larger than 2 by 2.

e. The capacity of each roof ventilator shall be that of the complete assembled unit and not that of the fan operating independent of the assembly.

f. All parts of the ventilators exposed to weather shall be painted with not less than two coats of weather-resistant enamel.

g. Each roof ventilator shall conform to the dimensional requirements as called for on the drawing.

19. Motors

a. Motors shall conform to the latest AIEE and NEMA standards except that motors on whose shafts fan wheels are mounted need not conform to NEMA frame and rating standards.

b. Motors shall be of phase, voltage, and frequency called for on the drawing and, except where otherwise called for, shall be squirrel-cage induction. Motors shall be open frame except as otherwise called for on the drawing.

c. Single-phase motors shall be inductive, split phase, or capacitor type.

d. Each motor shall have sufficient capacity and starting torque at high or low speed for all conditions of operation which its fan may impose, with a temperature rise not exceeding 40° C. above ambient 40° C. for open-frame motors and 55° C. above ambient 40° C. for totally enclosed and explosion-proof motors, but the rated capacity shall in no case be less than the brake horsepower of its fan, operating at specified conditions.

e. Stator coils and leads shall be thoroughly insulated, securely supported and braced for full-voltage start, and the completely wound stator shall be impregnated to withstand oil, moisture, and abrasive particles. A suitable conduit box shall be provided for the leads.

f. The rotor winding of squirrel-cage motors shall be of one-piece cast construction, aluminum or copper, or composed of copper bars so brazed, or otherwise attached, to the end rings as to form a mechanical and electrical bond equivalent to the solid bar.

g. Bearings shall be ball or roller type, sealed against the entrance of dust or escape of lubricant, and provided with adequate means for flushing the old lubricant when introducing new lubricant.

h. The motor for each belt-driven fan shall be mounted on a heavy-steel or cast-iron base having provisions for maintaining proper belt tension and alinement of the drive pulleys.

i. The frame, bearings, and mounting of each motor direct-connected to the fan which it drives shall be such as may be required to provide and maintain proper alinement under all conditions of operation.

BID SCHEDULE, EQUIPMENT DATA, AND SPECIFICATION NO. 000—TYPICAL AIR-CONDITIONING EQUIPMENT

BID SCHEDULE

Item	Articles or services	Quantity	Unit
1	Water chilling system ______ Name of manufacturer ______ Point of manufacture ______ (Street) (City) (State)	1	Only.
2	Condensing unit ______ Name of manufacturer ______ Point of manufacture ______ (Street) (City) (State)	1	Do.
3	Packaged air-conditioning unit ______ Name of manufacturer ______ Point of manufacture ______ (Street) (City) (State)	1	Do.
	ALTERNATE BID		
4	Lump sum for furnishing all equipment as specified under items 1, 2, and 3.	________	Lump sum.
5	Services of erecting engineer if required by the Authority (see paragraph 6 of Special Conditions).	________	Each per day or fraction thereof.

EQUIPMENT DATA

The undersigned bidder proposes to furnish equipment meeting the requirements of the specifications and of the following manufacture, type, size, and operating characteristics:

ITEM 1. WATER-CHILLING EQUIPMENT

General

Refrigerant ______

Overall capacity to cool ______ gpm water from 54° F. to 44° F. with 320-gpm condenser cooling water at an initial temperature of 75° F. under the following operating conditions:

Condensing temperature ______ degrees F.

Suction temperature ______ degrees F.

Overall floor space required ______

Maximum headroom required ______

Normal refrigerant charge ______

Normal oil charge ______

Gross weight ______

Compressors

Manufacturer ______

Number, size, and catalog designation ______

Number of cylinders ______ Bore and stroke ______

Rpm ______ Piston speed ______

Type of lubrication ______

Rated capacity ______ tons of refrigeration at ______ degrees F. suction and ______ degrees F. condensing temperature

Brake horsepower ______

Net weight ______

Compressor motors

Manufacturer ______

Type and frame No. ______

Horsepower ______ Full load, rpm ______

Full load, amperes ______

Locked rotor current, percent of full load, amperes ______

Full-load efficiency ________________________________
Starting torque, percent of full-load torque ________________
Maximum torque, percent of full-load torque ________________
Type and size of bearings __________________________
Net weight ____________________________________

Drives (if used)

Manufacturer ___________________________________
Pitch diameter, motor sheave _______________________
Pitch diameter, compressor sheave ____________________
Number and size of sections _______________________
Total capacity ________________________________ hp

Condensers

Manufacturer ___________________________________
Catalog designation _____________________________
Overall length ______________ Shell diameter__________
Water inlet size______________ Water outlet size ________
Refrigerant inlet size __________ Refrigerant outlet size ______
Tubes, number ______ size ______ length ______ number of passes ____
Head loss through condenser at 160 gpm _______________ feet
Condensing temperature _______________________ degrees F.
Rated capacity with 160-gpm incoming water at 75° F. __________ tons
Tested for ____________________ -psi water working pressure
and ____________________ -psi refrigerant working pressure
Net weight ____________________________________

Water coolers

Manufacturer ___________________________________
Catalog designation _____________________________
Overall length______________ Shell diameter__________
Water inlet size______________ Water outlet size ________
Refrigerant inlet size __________ Refrigerant outlet size ______
Tubes, number ______ size ______ length ______ number of passes ____
Head loss through water cooler at 180 gpm _______________ feet
Evaporating temperature _______________________ degrees F.
Rated capacity __________ tons with 180 gpm of water entering at 54° F.
Tested for ____________________ -psi water working pressure
and ____________________ -psi refrigerant working pressure
New weight ____________________________________

Auxiliary equipment

List of manufacturer's catalog designations, rated capacity of each piece of auxiliary equipment, controls, and safety devices.

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ITEM 2. CONDENSING UNIT

General

Refrigerant ______

Overall capacity ______ tons of refrigeration at 45° F. saturated suction temperature with 40-gpm condenser cooling water at an initial temperature of 75° F. with a condensing temperature of ____ degrees F.

Overall floor space required ______

Maximum headroom required ______

Normal refrigerant charge ______

Normal oil charge ______

Gross weight ______

Compressor

Manufacturer ______

Size and catalog designation ______

Number of cylinders ______ Bore and stroke ______

Rpm ______ Piston speed ______

Type of lubrication ______

Rated capacity ______ tons of refrigeration at ______ degrees F. suction and ______ degrees F. condensing temperature

Power required at motor shaft ______ bhp

Net weight ______

Compressor motor

Manufacturer ______

Type and frame No. ______

Horsepower ______ Full load, rpm ______

Full load, amperes ______

Locked rotor current, percent of full load, amperes ______

Net weight ______

Drive (if used)

Manufacturer ______

Pitch diameter, motor sheave ______

Pitch diameter, compressor sheave ______

Number and size of sections ______

Total capacity ______ hp

Condenser

Manufacturer ______

Catalog designation ______

Overall length ______ Shell diameter ______

Water inlet size ______ Water outlet size ______

Refrigerant inlet size ______ Refrigerant outlet size ______

Tubes, number ______ size ______ length ______ number of passes ______

Head loss through condenser at 40 gpm ______ feet

Condensing temperature ______ degrees F.

Rated capacity with 40-gpm incoming water at 75 F. ______ tons

Constructed for ______ -psi water working pressure and ______ -psi refrigerant working pressure

Net weight ______

Water regulating valve

Manufacturer ______ Catalog designation ______

Size ______ inches, pressure drop at 40 gpm ______ psi

Auxiliary equipment

List of manufacturer's catalog designation, rated capacity of each piece of auxiliary equipment, controls, and safety devices.

______

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ITEM 3. PACKAGED AIR-CONDITIONING UNIT

General

Manufacturer ______________________________
Refrigerant ______________________________
With 3,000 cfm air entering at 81° F. dry bulb and 67° F. wet bulb, leaving air __________ F. dry bulb and __________ F. wet bulb under the following conditions:

Condensing temperature ______________ degrees F.
Suction temperature ______________ degrees F.

With 3,000 cfm air entering at 60° F., leaving air __________ F. when supplied with saturated steam at 15 psi.
Overall floor space required ______________________________
Maximum height ______________________________
Gross weight ______________________________

Compressor

Manufactuer ______________________________
Number of cylinders ______________ Bore and stroke ______________
Rpm ______________ Piston speed ______________
Rated capacity ______________ tons of refrigeration at __________ F. suction and ______________ F. condensing temperature

Compressor motor

Manufacturer ______________________________
Horsepower ______________ Full load, rpm ______________
Full load, amperes ______________________________
Starting current, amperes ______________________________

Condenser

Manufacturer ______________________________
Catalog designation ______________________________
Tubes, number ______ size ______ length ______ number of passes __________
Head loss through condenser and regulating valve, passing 15 gpm ______ psi
Condensing temperature ______________________________
Rated capacity with 15 gpm of incoming water at 75° F. __________ tons of refrigeration.

Cooling coil

Manufacturer ______________________________
Catalog designation ______________________________
Size ______________ Face area ______________
Number of rows ______________ Fin spacing ______________
Type of metal, fins, and tubes ______________________________

Filters

Manufacturer ______________________________
Type ______________ Number of cells ______________
Size each cell ______________________________ inches
Rated capacity, each cell ______________________________ cfm

Fan

Manufacturer ______________________________
Type ______________________________
Capacity when operating against ⅜-inch static pressure ______________ cfm
Brake horsepower at rated capacity ______________________________
Rpm ______________________________

Fan motor

Manufacturer ______________________________
Type and frame No ______________________________
Horsepower ______________ Full load, rpm ______________
Full load, amperes ______________________________
Starting current, amperes ______________________________

Controls

List of manufacturer and type of all controls

____

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SPECIFICATION NO. 000

GENERAL PROVISIONS

1. The requirement

a. The work covered by these specifications comprises the designing, furnishing, and delivering water-chilling system, and/or condensing unit, and/or packaged air-conditioning unit for the various air-conditioning systems.

b. The water-chilling equipment, and/or condensing unit, and/or packaged air-conditioning unit shall be complete, including refrigerant compressor with motor and drive, condenser, water cooler (where required), all refrigerant piping, insulation, and all necessary and customary auxiliary equipment and accessories. Included shall be provisions for lubrication, control and indicating instruments, and all necessary and specified safety and protective devices.

c. TVA will furnish all electrical wiring, conduit, magnetic starting, and disconnect switches for motors, anchor bolts, and will install all equipment.

2. The engineer

a. Work under this specification shall be subject to the approval of the Chief Engineer of TVA, hereinafter referred to as "the engineer," acting directly or through properly authorized agents, who shall determine the amount, quality, acceptability, and fitness of the several kinds of work and materials which are to be furnished hereunder and who shall decide all questions which may arise as to measurement of quantities and the fulfillment of the technical requirements of the specification.

3. Drawings and data to be furnished by the contractor

a. Within 30 days after notice of award of contract the contractor shall furnish two copies of assembly and detailed drawings, cuts, and data sheets in such detail as necessary for installation, operation, and maintenance of the equipment and for demonstrating that it complies with the requirements of the specifications.

b. All drawings shall be subject to the approval of the engineer and shall be clearly identified by serial numbers and descriptive titles indicating their application to the contract.

c. The engineer will, within ten days after receipt of prints of drawings for approval, forward one copy to the contractor marked "Approved," "Approved with Correction as Noted," or "Returned for Correction."

d. The contractor shall make necessary corrections and revisions on drawings "Approved with Correction as Noted" and on drawings "Returned for Correction," and he shall submit prints for approval in the same routine as before. Time required for such revision of drawings and resubmission of prints will not entitle the contractor to any extension of time, but the engineer will examine and return such prints as promptly as possible.

e. Any work done by the contractor prior to receipt of drawings "Approved" or "Approved with Correction as Noted" by the engineer shall be at the contractor's risk. When the corrections have been made on drawings "Approved with Correction as Noted," such drawings may be used for fabrication unless specifically stated otherwise by the engineer.

f. Approval by the engineer shall not relieve the contractor of the responsibility for the correctness of the drawings furnished by the contractor nor for their compliance with the specifications.

g. The drawings and data shall include but not necessarily be limited to:

(1) For items 1 and 2—

- (a) Complete assembly drawings showing the various pieces of equipment as assembled in the complete unit.
- (b) Refrigerant and water flow diagrams.

(c) Control and electric wiring diagrams.
(d) Foundation and bolt-setting diagrams or drawings.
(e) Outline drawings of the principal pieces of equipment showing major dimensions.
(f) Electric motor data sheets showing outlines, principal dimensions, location of anchor bolts and conduit connection, and name plate rating.
(g) General and detail assembly drawings, catalog pages, printed cuts or dimension sheets of necessary and minor equipment and control and safety devices, including complete wiring diagrams of all electrical equipment.
(h) Installation and operating instructions.
(i) Motor test report (item 1 only).

(2) For item 3—

(a) Complete assembly drawings showing the various pieces of equipment as assembled in the complete unit.
(b) Control and electric wiring diagrams.
(c) Outline drawings of the principal pieces of equipment showing principal dimensions.
(d) Foundation and bolt-setting diagrams or drawings.
(e) General and detail assembly drawings, catalog pages, printed cuts or dimension sheets of accessory and minor equipment, and control devices, including complete wiring diagrams of all electrical equipment.
(f) Installation and operating instructions.

h. Upon final approval of all drawings the contractor shall furnish, for the permanent files of TVA, six copies of each drawing and data sheet.

i. Before shipment the contractor shall furnish to the engineer nine copies each of the motor test reports for item 1 as called for in the motor sections. These reports shall be certified by a responsible representative of the manufacturer. Reports shall be subject to the approval of the engineer.

4. Equipment

a. All equipment shall be new and of latest design, shall be of first-grade quality as to material and workmanship, and shall be such as has been proved to be suitable for the intended purpose.

b. Incidental fittings, fixtures, accessories, and supplies shall be of approved manufacture and standard first-grade quality.

5. Access to work

a. The engineer and his assistants and other agents of TVA shall at all times have access to all places where work is being done under this contract, and they shall have full facilities for unrestricted inspection of such work.

6. Shop inspection

a. No material or equipment shall be shipped from its point of manufacture before it has been inspected, unless the engineer authorizes inspection to be made elsewhere.

b. The acceptance of any material or equipment shall in no way relieve the contractor of any of his responsibility for meeting all of the requirements of the specification, and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

7. Marking

a. All parts or units of assembly shall be adequately marked. Marks, which shall be in accordance with drawings, shall be clearly legible and so placed as to be readily visible when the part is being erected in the field. All pieces weighing more than one ton shall have the approximate weight marked thereon.

b. Connecting parts, assembled in the shop, shall, before dismantling for shipment, be match-marked to facilitate erection in the field. The location of the match marks shall be clearly indicated.

8. Preparation for shipment

a. The contractor shall prepare all materials and articles for shipment in such manner as to facilitate handling and to protect them from damage in transit. Boxes and crates shall be marked and have a packing list enclosed showing the parts contained therein.

b. All finished surfaces shall be coated with an approved rust preventive.

9. Tests

a. TVA will make all tests necessary during and after installation at its own expense. The contractor shall furnish, at such times and for such periods as required by TVA, the services of a competent engineer to supervise and direct the installation, charging, and putting into operation of the system and to assist the engineer in making the necessary tests in accordance with item 5 of the bid schedule.

DETAILED REQUIREMENTS—ITEM 1

10. General description

a. The water-chilling system shall have capacity to cool a total of not less than 360 gallons per minute of water from 54° F. to 44° F. with a total of 320 gallons per minute of condenser cooling water at a maximum supply temperature of 75° F.

b. The refrigerating system shall be designed for operation at not less than 35° F. suction. Raw, strained, untreated water will be supplied for condensing of quantity and temperature as specified elsewhere.

c. The system shall be designed consisting of two identically sized assemblies, each with compressor, compressor motor, drive (if needed), condenser, water cooler, and accessory equipment. The two assemblies shall be arranged as a single installation, suitable for mounting on a single concrete pad. Each assembly shall be complete in itself, requiring no cross connection of refrigerant, water, or electrical service. TVA will provide separate electrical service to each compressor and separate water connections to each of the water coolers and condensers. Each compressor shall be controlled by a separate single-pole, single-throw thermostat, furnished by TVA and mounted in a central chilled water storage tank.

d. The entire system of both assemblies and accessory equipment shall be designed and arranged in a neat and compact unit to fit into a space measuring 22 feet long by 18 feet wide by 9 feet high. All parts shall be arranged and placed so as to be readily accessible for inspection and maintenance. Adequate space for tube removal is available outside the above space requirements.

11. The refrigerant

a. The refrigerant shall be noninflammable, nontoxic, and nonexplosive, shall have the pressure and temperature characteristics suitable for the application, and shall be as stated by the contractor in his bid.

12. Refrigerant compressors

a. Each compressor shall be of the single-acting, multicylinder type, designed to operate at a speed not exceeding that recommended by the manufacturer in accordance with ratings listed in his published catalog, but the piston speed shall in no case exceed 650 feet per minute. They shall be of standard manufacture and designed for operation with the refrigerant specified. Each compressor shall be rugged and of heavy construction, so arranged that all parts are readily accessible for maintenance and repair, and shall be provided with an approved shaft seal which will effectively hold the loss of the refrigerant to a minimum. Suitable provision shall be made to ensure adequate and proper automatic lubrication of cylinder walls, bearings, and other moving parts, and to prevent undue consumption of lubricating oil or its dissipation from the crank case to other parts of the refrigerating system. If the design of the compressor includes an outboard bearing, an approved type of oil or grease lubrication may be substituted for the automatic lubrication of this bearing.

b. Each compressor shall be mounted on suitable resilient base, together with the motor and drive, to effectively dampen vibration and reduce its transmission into the structure. Each base shall be of steel and rubber or steel and steel spring construction, carefully designed for the loading and frequency of vibration to which it will be subjected. Each compressor shall be equipped with the necessary protective and safety devices, refrigerant control and indicating devices as specified hereinafter.

13. Drives (if used)

a. The drives shall be of the v-type, the number of belts being not less than that required according to the belt manufacturer's published ratings, plus such additional belts as required by the character of the service and the maximum

load to be transmitted. Each v-belt shall be of endless rubber fabric and not lighter than "C" section. The compressor pulley shall be of ample weight to provide adequate flywheel effect.

14. Compressor motors

a. The compressor motors shall be 440-volt, 3-phase, 60-cycle, squirrel-cage, full-voltage start, low-starting current, open-frame, induction motors conforming to the latest AIEE and NEMA standards. The motors may be normal starting torque if its compressor is provided with initial unloading or they shall be high-starting torque if no initial unloading is provided.

b. Each motor shall have sufficient capacity for all conditions of starting and continuous operating which the compressor may impose, with a temperature rise not exceeding 40° C. above an ambient temperature of 40° C., and shall have a name plate rating of not less than compressor brake horsepower, at a speed not to exceed 1,200 revolutions per minute.

c. The bearings shall be dusttight, ball, roller, or sleeve type, with adequate means for flushing the old lubricant when introducing new lubricant and for retaining the correct amount of lubricant without dripping.

d. Routine tests in accordance with NEMA Standard MG1–4.24 shall be performed on each motor. These tests will not be witnessed by TVA.

e. The contractor shall furnish TVA nine certified copies of the results from the tests called for above.

15. Refrigerant condensers

a. Each condenser shall be of the water-cooled, shell-and-tube type, having ample heat exchange surface to provide, with 160-gallon-per-minute condensing cooling water, the necessary condensing temperature, in conjunction with the water cooler and compressor specified, required to allow the equipment to stay within the limits of power specified. A scale factor of 0.0005 shall be used in the design of each condenser.

b. The water passages of each condenser shall be so arranged that the condenser cooling water will be distributed and circulated in an efficient manner, both as regards heat transfer and conservation of power required for the circulation of the water.

c. The head loss through each condenser when passing 160 gallons per minute of cooling water shall not exceed 25 feet.

d. After assembly the refrigerant spaces shall be tested for refrigerant working pressure of not less than 200 pounds per square inch and the water spaces shall be tested for a working pressure of not less than 100 pounds per square inch.

e. Each condenser shall be of such size that the full refrigerant charge of the system may be contained therein, or a suitable refrigerant receiver shall be furnished in addition to the condenser.

f. If refrigerant receivers are furnished they shall be of ample size to contain the whole refrigerant charge; the design and construction shall be as specified for the condenser shell; and they shall have devices for relieving excessive pressures and for indicating the quantity of refrigerant.

g. Each condenser shall be so designed and arranged to allow the removal and replacement of individual tubes.

16. Water coolers

a. Each water cooler shall be of the shell and tube type with adequate heat exchange surface for the specified performance and shall be carefully designed for efficient operation, both as regards distribution of refrigerant and the conservation of power required for the circulation of water through it. A scale factor of 0.0005 shall be used in the design of these coolers.

b. The head loss through each water cooler, when passing 180 gallons per minute of water, shall not exceed 25 feet.

c. After assembly the refrigerant spaces shall be tested for refrigerant working pressure of not less than 200 pounds per square inch, and the water spaces shall be tested for a working pressure of not less than 100 pounds per square inch.

d. Each cooler shall be provided with all necessary devices for the controlled distribution and circulation of the refrigerant. Provision shall be made as necessary for preventing the accumulation of lubricant in the cooler. Each cooler shall be furnished with devices for indicating the quantity, temperature, and pressure of the refrigerant, and the entering and leaving temperatures of

the water, and shall have adequate protection against freezing and excessive pressures.

e. The water cooler shall be so designed and arranged to allow the removal and replacement of individual tubes.

17. Stand for condensers and water coolers

a. The condensers and water coolers shall be mounted above or alongside the compressors. The contractor shall furnish a rigidly constructed structural steel stand for the support of the condensers and water coolers. Suitable saddles shall be provided for support of the equipment, and proper clearance shall be allowed for 2-inch thickness of insulation on the water coolers.

18. Refrigerant pipe and fittings

a. The contractor shall furnish all refrigerant pipe, fittings, and auxiliary apparatus required for the complete installation and interconnection of the water-cooling and refrigerating equipment in each assembly of the system.

b. Pipe for conveying the refrigerant shall be seamless and shall be either of hard-drawn copper type K, except pipe ⅝-inch outside diameter or smaller may be soft, or of steel meeting the requirements of ASTM Specification A53–47 "Welded and Seamless Steel Pipe" of sufficient weight and strength required by the service. All pipe shall be of adequate size for the purpose for which it is intended and shall be routed in a simple and direct manner.

c. All pipe larger than 1-inch outside diameter shall be accurately cut and formed to dimension, fitted, and assembled with its fittings insofar as possible before delivery.

d. If copper tubing is used for the refrigerant piping, all fittings shall be of extra-heavy wrought copper or of forged brass, except that such type of fittings that are not commercially available in either of the above materials may be cast brass or bronze. All cast-brass or bronze fittings shall be heavily tinned on both sides. All fittings larger than ⅝-inch outside diameter shall be soldered, and fittings of ⅝-inch outside diameter and smaller may be soldered or flared.

e. If steel tubing is used for the refrigerant piping, all shopmade joints and connections shall be welded. All fittings for field installation or connection shall be welded except that connections to valves and other specialties shall be made with ammonia-type flanges.

19. Insulation

a. The contractor shall furnish vegetable cork insulation of ice-water thickness for the water cooler and suction line piping and fittings. The water cooler shall be insulated with lagging strips, securely applied by hot-dip asphalt, completely sealed with a trowel coat of suitable waterproof mastic compound. The piping shall be insulated with ice-water thickness sectional vegetable cork insulation. The fittings shall be insulated with moulded vegetable cork, and all cracks and joints shall be filled and pointed up with suitable waterproof mastic compound.

20. Refrigerant specialties

a. The contractor shall furnish all shutoff valves, float valves, and other devices required to govern the flow of refrigerant. All such valves and devices shall be of standard manufacture of characteristics applicable to the service and of adequate capacity to pass the required refrigerant under all conditions of temperature and pressure under which the refrigerating equipment may be operated. Valves shall be packless or capped in such manner as to effectively prevent loss of refrigerant. Solenoid valves and other devices requiring electrical connections shall be for 110-volt, single-phase, 60-cycle current and shall be provided with suitable terminal box having removable cover and provisions for conduit connections.

b. The contractor shall furnish strainers, driers, and such other like apparatus as may be necessary to keep the refrigerant clean and dry. He shall furnish also any equipment which may be necessary for the return of lubricant to the compressor and for purging of air from the refrigerant system and from the individual pieces of equipment.

21. Indicating instruments

a. The contractor shall furnish indicating instruments to show suction and compression pressures. There shall also be provided suitable devices for indicating the flow of refrigerant in the system. All instruments and indicating devices shall be of standard manufacture, accurately calibrated with easily legible scales. Pressure gauges shall have dials not less than 4½ inches in diameter. Mercury column thermometers shall have scale lengths not less than 9 inches.

22. Safety devices

a. The contractor shall supply all necessary, customary, or specified safety devices for protection of the equipment, TVA's structure, TVA's operators, and the public.

23. Operating supplies and equipment

a. The contractor shall furnish 1½ full charges of refrigerant and 2 full charges of lubricating oil. The refrigerant and oil shall be the best commercial grades of the type for which the refrigerating machinery is designed. Each shall be clean, pure, and thoroughly dehydrated, and shall bear the recommendation of the manufacturer of the machinery. The refrigerant and oil shall be delivered in suitable containers which shall remain the property of TVA.

24. Tools

a. The contractor shall furnish all tools and accessory equipment required for the maintenance and operation of and simple repairs to the equipment which he furnishes. The tools shall include but not be limited to special wrenches and screw drivers to fit all bolts, nuts, and screws and the necessary instruments and apparatus for testing for leaks and for indicating quantity and flow of refrigerant, and all apparatus necessary for charging the equipment with refrigerant and lubricant.

DETAILED REQUIREMENTS—ITEM 2

25. General description

a. The condensing unit to be furnished is intended for application for use with two direct expansion blast coils equal to Aerofin type CHDE, No. 86, which will be furnished by TVA. The velocity of air passed over the coils is 400 feet per minute. The equipment shall have a capacity of not less than 23 tons of refrigeration with 40 gallons per minute of condenser cooling water at a maximum supply temperature of 75° F.

b. The condensing unit shall be designed for operation at 45° F. suction. Raw, strained, untreated water will be supplied for condensing of quantity and temperature as specified elsewhere.

c. The design of the components parts of the condensing unit shall be such that the power required to drive the compressor, under specified condition of operation, will not exceed 25 brake horsepower, measured at the motor shaft.

d. The equipment shall be designed with compressor, compressor motor, drive (if needed), condenser, and accessory equipment arranged in a neat and compact unit to fit into a space measuring 9 feet long by 4 feet wide by 6 feet high. All parts shall be arranged and placed so as to be readily accessible for inspection and maintenance. Adequate space for tube removal is available outside the above space requirements.

26. The refrigerant

a. The refrigerant shall be noninflammable, nontoxic, and nonexplosive, shall have the pressure and temperature characteristics suitable for the application, and shall be as stated by the contractor in his bid.

27. Refrigerant compressor

a. The compressor shall be of the single-acting, multicylinder type, designed to operate at a speed not exceeding that recommended by the manufacturer in accordance with ratings listed in his published catalog, but the piston speed shall in no case exceed 650 feet per minute. It shall be of standard manufacture and designed for operation with the refrigerant specified. The compressor

shall be rugged and of heavy construction, so arranged that all parts are readily accessible for maintenance and repair, and shall be provided with an approved shaft seal which will effectively hold the loss of the refrigerant to a minimum. Suitable provision shall be made to ensure adequate and proper automatic lubrication of cylinder walls, bearings, and other moving parts, and to prevent undue consumption of lubricating oil or its dissipation from the crank case to other parts of the refrigerating system. If the design of the compressor includes an outboard bearing, an approved type of oil or grease lubrication may be substituted for the automatic lubrication of this bearing.

b. The compressor shall be mounted on suitable resilient base, together with the motor and drive, to effectively dampen vibration and reduce its transmission into the structure. The base shall be of steel and rubber or steel and steel spring construction, carefully designed for the loading and frequency of vibration to which it will be subjected. The compressor shall be equipped with the necessary protective and safety devices, refrigerant control, and indicating devices as specified hereinafter.

28. Drive (if used)

a. The drive shall be of the V-type, the number of belts being not less than that required according to the belt manufacturer's published ratings, plus such additional belts as required by the character of the service and the maximum load to be transmitted. Each V-belt shall be of endless rubber fabric and not lighter than "B" section. The compressor pulley shall be of ample weight to provide adequate flywheel effect.

29. Compressor motor

a. The compressor motor shall be a 440-volt, 3-phase, 60-cycle, squirrel-cage, full-voltage start, low-starting current, open frame, induction motor conforming to the latest AIEE and NEMA standards. The motor may be normal starting torque if the compressor is provided with initial unloading or it shall be high starting torque if no initial unloading is provided.

b. The motor shall have sufficient capacity for all conditions of starting and continuous operation which the compressor may impose, with a temperature rise not exceeding 40° C. above an ambient temperature of 40° C., and shall be 25-horsepower at a speed not to exceed 1,200 revolutions per minute.

c. The bearings shall be dusttight, ball, roller, or sleeve type, with adequate means for flushing the old lubricant when introducing new lubricant and for retaining the correct amount of lubricant without dripping.

30. Refrigerant condenser

a. The condenser shall be of the water-cooled, shell-and-tube type, having ample heat exchange surface to provide, with condensing cooling water as hereinbefore specified, the necessary condensing temperature, in conjunction with the water cooler and compressor specified, required to allow the equipment to stay within the limits of power specified. A scale factor of 0.0005 shall be used in the design of this condenser.

b. The water passages of the condenser shall be so arranged that the condenser cooling water will be distributed and circulated in an efficient manner, both as regards heat transfer and conservation of power required for the circulation of the water.

c. The head loss through the condenser when passing 40 gallons per minute cooling water shall not exceed 25 feet.

d. After assembly the refrigerant spaces shall be tested for refrigerant working pressure of not less than 200 pounds per square inch and the water spaces shall be tested for a working pressure of not less than 100 pounds per square inch.

e. The condenser shall be of such size that the full refrigerant charge of the system may be contained therein, or a suitable refrigerant receiver shall be furnished in addition to the condenser.

f. If a refrigerant receiver is furnished it shall be of ample size to contain the whole refrigerant charge; the design and construction shall be as specified for the condenser shell; and it shall have devices for relieving excessive pressures and for indicating the quantity of refrigerant.

31. Water regulating valve

a. A water regulating valve shall be provided on the water inlet side of the condenser to shut off the water to the condenser when the compressor stops.

The valve shall have a pressure drop not to exceed 20 pounds per square inch when passing 40 gallons per minute of condensing water.

32. Refrigerant pipe and fittings

a. The contractor shall furnish all refrigerant piping between the component parts of the refrigerating equipment, all necessary pipe and fittings to connect direct-expansion cooling coils furnished by TVA, 40 feet of suction piping, 40 feet of liquid piping, six 90-degree ells for suction piping, and six 90-degree ells for liquid piping. The liquid pipe shall be 1⅛ inches o.d. and the suction pipe shall be 2⅝ inches o.d.

b. The correct relation between the refrigerating equipment and cooling coils has not been established. TVA will utilize the 40 feet of pipe and six ells for both the suction and liquid connections to connect the two parts in the field.

c. Pipe for conveying the refrigerant shall be seamless and shall be of hard-drawn copper type K, except pipe ⅝-inch outside diameter or smaller may be soft, of sufficient weight and strength required by the service. All pipe shall be of adequate size for the purpose for which it is intended and will be routed in a simple and direct manner.

d. The copper tubing and all fittings shall be of extra-heavy wrought copper. All fittings larger than ⅝-inch outside diameter shall be soldered, and fittings of ⅝-inch outside diameter and smaller may be soldered or flared.

33. Insulation

a. The contractor shall furnish vegetable cork insulation of ice-water thickness for the suction line piping and fittings being furnished by him. The piping shall be insulated with ice-water thickness sectional vegetable cork insulation. The fittings shall be insulated with moulded vegetable cork, and all cracks and joints shall be filled and pointed up, with suitable waterproof mastic compound.

34. Refrigerant specialties

a. The contractor shall furnish all valves, specialties, and devices required to govern the flow of refrigerant, including 2 thermal expansion valves, 2 solenoid valves, and 2 liquid strainers for the direct-expansion coils which will be furnished by TVA. All such valves and devices shall be of standard manufacture of characteristics applicable to the service and of adequate capacity to pass the required refrigerant under all conditions of temperature and pressure under which the refrigerating equipment may be operated. Valves shall be packless or capped in such manner as to effectively prevent loss of refrigerant. Solenoid valves and other devices requiring electrical connections shall be for 110-volt, single-phase, 60-cycle current and shall be provided with suitable terminal box having removable cover and provisions for conduit connections.

b. The contractor shall furnish strainers, driers, and such other like apparatus as may be necessary to keep the refrigerant clean and dry. He shall furnish also any equipment which may be necessary for the return of lubricant to the compressor and for purging of air from the refrigerant system and from the individual pieces of equipment.

35. Indicating instruments

a. The contractor shall furnish indicating instruments to show suction and compression pressure. There shall also be provided suitable devices for indicating the quantity of refrigerant in the system. All instruments and indicating devices shall be of standard manufacture, accurately calibrated with easily legible scales. Pressure gages shall have dials not less than 2½ inches in diameter. Mercury column thermometers shall have scale lengths not less than 9 inches.

36. Safety devices

a. The contractor shall supply all necessary, customary, or specified safety devices for protection of the equipment, TVA's structure, TVA's operators, and the public.

37. Operating supplies and equipment

a. The contractor shall furnish 1½ full charges of refrigerant and 2 full charges of lubricating oil. The refrigerant and oil shall be the best commercial

grades of the type for which the refrigerating machinery is designed. Each shall be clean, pure, and thoroughly dehydrated, and shall bear the recommendations of the manufacturer of the machinery. The refrigerant and oil shall be delivered in suitable containers which shall remain the property of TVA.

38. Tools

a. The contractor shall furnish all tools and accessory equipment required for the maintenance and operation of and simple repairs to the equipment which he furnishes. The tools shall include but not be limited to special wrenches and screw drivers to fit all bolts, nuts, and screws and the necessary instruments and apparatus for testing for leaks and for indicating quantity and flow of refrigerant, and all apparatus necessary for charging the equipment with refrigerant and lubricant.

DETAILED REQUIREMENTS—ITEM 3

39. General description

a. The packaged air-conditioning unit shall be a standard floor-mounted air-conditioning unit with vertical fan discharge. The unit shall deliver 3,000 cubic feet per minute of air against an external static pressure of three-eighth inch of water. TVA will make all air duct, water, and electrical connections.

b. The unit shall be designed to cool the 3,000 cubic feet per minute of air from 81° F. dry bulb and 67° F. wet bulb to a maximum of 63° F. dry bulb and 58½° F. wet bulb when supplied with 15 gallons per minute of condenser cooling water at a maximum supply temperature of 75° F.

c. Raw, strained, untreated water will be supplied for condensing of quantity and temperature as stated above.

d. The unit shall be designed and assembled with compressor, motor, condenser, cooling coil, humidifier, filters, return connection, fresh air connection, fan with motor and drive, fan starter controls, and accessory equipment arranged and assembled in a neat and compact unit. All parts shall be arranged and placed so as to be readily accessible for inspection and maintenance.

e. The unit shall be arranged so that all services, electric and water can be connected at the rear or on the side.

40. The refrigerant

a. The refrigerant shall be noninflammable, nontoxic, and nonexplosive, and shall have pressure temperature characteristics suitable to the application, and shall be as stated by the contractor in his bid.

41. Refrigerant compressor

a. The compressor shall be of the single-acting, multicylinder type, in a complete unit with its driving motor. It shall be of standard manufacture and designed for operation with the refrigerant specified. The compressor shall be rugged and of heavy construction.

42. Motors

a. The compressor and fan motors shall be for 440-volt, 3-phase, 60-cycle current. The motors shall be full-voltage start, high-starting torque, low-starting current induction motors conforming to the latest AIEE and NEMA standards except the compressor motor may not conform to a standard NEMA frame.

43. Refrigerant condenser

a. The condenser shall be water-cooled, shell-and-tube type having ample heat exchange surface to maintain, with the condenser cooling water as herein before specified, a refrigerant condensing pressure which, in conjunction with the compressor specified, will be such that the power required to operate the equipment will not exceed the capacity of the compressor motor. A scale factor of 0.0005 shall be used in the design of this condenser.

b. The head loss through each condenser and automatic regulating valve, when passing the required quantity of cooling water, shall not exceed 18 pounds per square inch.

44. Cabinet

a. The entire unit consisting of all hereinbefore specified parts shall be contained in a cabinet of neat appearance and modern design corresponding to the manufacturer's latest current design. The cabinet shall be finished outside in a baked enamel corresponding to the manufacturer's standard practice.

b. The cabinet shall be fabricated from sheet steel, bonderized to resist corrosion. All parts exposed to moisture shall be galvanized.

45. Cooling coil

a. The cooling coil shall be of standard manufacture, direct expansion finned-tube type, of sufficient number of rows to produce the specified cooling when passing the specified amount of air based on the designed suction conditions of the compressor.

46. Humidifier

a. The unit shall be furnished with a humidifier to add moisture automatically. The humidifier shall consist of a mist nozzle, solenoid valve, strainer, and an adjustable humidistat.

47. Filters

a. The unit shall be so arranged that both fresh and recirculated air pass through the filter section.

b. The filters shall be of the throw-away or washable type, easily accessible and of sufficient area to adequately filter the specified amount of air.

48. Insulation

a. The cabinet shall be thermally and acoustically insulated by means of modern insulating materials. The motor-compressor assembly shall be rubber and/or spring-mounted. Flexible metallic tubing shall be used to prevent vibration from being transmitted to cabinet or floor.

49. Controls

a. All cooling shall be thermostatically controlled by a thermostat. A selector switch shall be provided to allow the unit to run on cooling or fan alone.

b. The refrigerant flow shall be controlled by a thermal expansion valve. A refrigerant line strainer shall be provided.

c. An automatic water regulating valve shall be furnished to control the water flow through the condenser.

50. Electrical connections

a. The unit shall be designed and arranged for connection to a single 440-volt, 3-phase, 60-cycle circuit. TVA will provide a single, fused disconnect switch for the service to the unit.

b. The unit shall be equipped with motor magnetic starters, selector switch, overload devices, and controls.

APPENDIX D

CONSTRUCTION SPECIFICATIONS

Appendix D includes typical construction specifications prepared by the Mechanical Design Branch and issued to the field construction forces for their guidance in installing equipment or applying materials. Construction specifications covering field erection of hydraulic turbines are included in appendix A.

The specifications contained in this appendix are: Page

CONSTRUCTION SPECIFICATION NO. FLM–678—FOR APPLYING INSULATION TO AIR-CONDITIONING DUCTS, EQUIPMENT, AND GENERATOR HATCH COVERS, FORT LOUDOUN PROJECT

(Reference drawings not included in this report)

SECTION 1. *General.*—These specifications cover the application of insulating materials for all air-conditioning supply ducts, air-conditioning supply fans, air-conditioning plenums, chilled-water storage tank, water cooler, chilled-water piping, refrigerant piping, and generator hatch covers.

SEC. 2. *Scope of work.*—The surfaces to be insulated under this specification include all sheet-metal supply ducts of the air-conditioning system, the air-conditioning plenum as shown on the drawings, the air-conditioning fans (Marks 47N731-1, -2, and -17), chilled-water piping, refrigerant-suction piping, the water cooler, the chilled-water storage tank, and the generator hatch covers. All projecting flanges, ribs, and other secondary surfaces shall also be insulated. Return ducts and pumps are not to be insulated.

SEC. 3. *Drawings.*—The sheet-metal surfaces to be insulated are shown on the following drawings, which bear the general title "Fort Loudoun Project, Powerhouse, Control Building, Heating and Ventilating," with individual designations as follows:

Drawing	*Title*
47N738	Grille details
47N801	Plan elevation 796.0
47N802	Plan elevation 812.0
47N803	Plan elevation 824.0
47N804	Plan elevation 837.0
47N811	Sections and details sheet 1
47N812	Sections and details sheet 2
47N813	Sections and details sheet 3
47N814	Sections and details sheet 4
47N821	Refrigeration and water-cooling equipment and piping
47N822	Chilled-water piping
47N831	Miscellaneous details plenum framing sheet 1
47N832	Miscellaneous details plenum framing sheet 2
47N833	Miscellaneous details plenum framing sheet 3
47N834	Miscellaneous details plenum framing sheet 4

and structural steel drawing No. 48N314, entitled "Generator Cover."

SEC. 4. *Materials.*—All material required for insulating the sheet-metal surfaces, fans, piping, equipment, and generator covers mentioned in this specification, except the galvanized steel straps and seals, were purchased under requisition 327381. Two hundred pounds of ½-inch galvanized steel strap (5,800 feet) and 2,000 Acme No. 42 insulation seals, together with an Acme No. SPB stretcher and an Acme No. 4CP sealer, were purchased November 11, 1937, under requisition No. 132788R, Schedule XI, Order K–37–18534, from the Acme Steel Co., 2840 Archer Ave., Chicago, Ill., for use in the Pickwick Landing powerhouse.

The stretcher and a quantity of strapping and seals were transferred to Guntersville, Chickamauga, Hiwassee, Watts Bar, Cherokee, and then to Apalachia. The stretcher is available for transfer to other projects of the Authority upon completion of the work at Apalachia. The Fort Loudoun field office should issue a requisition for transfer of the stretcher and sealer and any surplus material from the Apalachia project, or from such other project as may have subsequently acquired it. Additional strap and seals should be procured by the field as required. The original cost of the stretcher was $12, and the sealer $8.

SEC. 5. *Procedure for application of rock cork to ducts.*—The ducts shall first be brushed free of all plaster and other foreign material. The ductwork shall receive one coat of Johns-Manville concrete primer and be allowed to dry. A heavy coat of Johns-Manville fibrous adhesive shall be applied to the duct, covering only enough area at a time to receive one sheet of rock corkboard. The corkboard shall be so placed on the plastic-coated duct that its entire area will be in contact with the duct and make good bond.

After placement, the corkboard shall be secured to the duct with No. 14 by 1½-inch-long sheet-metal screws, using galvanized sheet-metal washers, approximately 2 inches square, cut from scrap. After the perimeter of a section of duct work has been covered, ½-inch-wide galvanized steel strapping shall be applied on 1-foot centers, using 1½-inch by 1½-inch by 24-gage by 3-inch-long field-fabricated corner angles over the insulating board. Where it is not practicable to use steel bands around the duct for holding the insulation in place, the corkboard shall be secured in place by additional sheet-metal screws and galvanized washers. The screws shall be placed close enough together that they will hold the insulating board securely to the duct. Upon completion of placement of all corkboard, apply a light coat of Johns-Manville concrete primer and then an extra heavy coat of Johns-Manville "Zerogloss."

SEC. 6. *Procedure for application of rock cork to plenums and fans.*—The fans and plenums shall first be brushed free of all plaster and other foreign material. One coat of Johns-Manville concrete primer shall be applied to the fans and plenums.

The Plenum.—The side of the rock corkboard to be placed on the plenum shall be dipped in hot asphalt, making sure that all edges are dipped. After dipping the board shall be firmly placed on the plenum and secured in place with No. 14 sheet metal screws, 1½ inches long, using galvanized sheet metal washers. After placement of the corkboard, the plenum shall receive a light coat of Johns-Manville concrete primer and two ⅛-inch trowel coats of Johns-Manville "Aertite" coating.

The Fans.—Fans, marks 47N731–1, –2, and –17, shall be insulated completely. The side of the corkboard to be placed on the fan shall be dipped in hot asphalt, making sure that all edges of the sheet are dipped. After dipping, the corkboard shall be firmly placed on the fan. The corkboard on the fan scroll shall be held in place with ½-inch-wide galvanized steel strapping. Care shall be exercised that all projecting flanges or ribs on which condensation may occur be adequately covered. After placement of the corkboard, the fan shall receive a light coat of Johns-Manville concrete primer and two ⅛-inch trowel coats of Johns-Manville "Aertite" coating.

SEC. 7. *Procedure for applying rock cork lagging to storage tank.*—The tank shall first be brushed free of all plaster and other foreign material. The tank shall receive one coat of Johns-Manville concrete primer. Rock cork lagging strips shall be applied as follows:

> The lagging strips shall be dipped in hot asphalt, making sure that all edges are dipped, and firmly placed on the tank. After the shell of the tank has been covered, ½-inch-wide galvanized steel strapping shall be

used on 1-foot centers. The heads of the tank shall be covered with two layers of 1-inch-thick rock cork, cut as required for coverage and cemented in place with hot asphalt. After placement, the lagging strips shall be given a light coat of Johns-Manville concrete primer and finished with two ⅛-inch-thick trowel coats of Johns-Manville "Aertite" coating.

SEC. 8. *Procedure for applying rock cork lagging to water cooler.*—The insulation of the water cooler shall be identical with the procedure for insulating the storage tank (see sec. 7). *No insulation should be applied to the water cooler or refrigerant piping until the system has been operated several days and all refrigerant leaks definitely have been made tight.*

SEC. 9. *Procedure for applying rock cork section pipe insulation.*—Before any insulation is applied, pipe and fittings shall have been tested, made tight, cleaned of rust, scale, or other foreign matter, and made dry.

All pipes shall be supported on metal saddles placed over the insulation. A galvanized iron shield, not lighter than No. 18 gage, at least as long as the outside diameter of the insulation and extending halfway up each side, shall be snugly fitted under the line at each hanger point.

Before each section of insulation is applied, both longitudinal joints and one of the end joints shall be coated with Johns-Manville "Zeroseal," and the pipe shall be painted with one coat of Johns-Manville "Zerogloss." After placing the section of insulation on the pipe, it shall be closed and temporarily secured with staples furnished for this purpose. The coated end shall next be butted tight against the uncoated end of the previously applied section. The insulation shall be so placed that the longitudinal joints occur at the top and bottom of the pipe.

The area to be covered by the waterproof lap shall be coated with Johns-Manville "Zeroseal" and the lap pressed smoothly into it. The end joint shall then be sealed with two plies of 3-inch-wide Johns-Manville "Zerotape" embedded in a coat of Johns-Manville "Zeroseal."

The section shall be permanently secured in place with soft iron wire 6 inches on centers. After the sectional pipe covering has been applied and secured in place, it shall be covered with one coat of Johns-Manville "Zerogloss."

SEC. 10. *Procedure for applying insulation to pipe fittings.*—Before any fitting insulation is applied, ends of the adjoining pipe insulation shall be coated with Johns-Manville "Zeroseal." The fitting shall then be given one brush coat of Johns-Manville "Zerogloss." Johns-Manville "Zerotex" shall be wrapped around the fitting until there is a sufficient quantity to shape into a fitting cover slightly thicker than the pipe insulation, and the outer ply shall be extended about 1 inch over the end of the adjoining pipe insulation. The "Zerotex" shall be drawn down tightly over the fitting with jute twine and two layers of Johns-Manville "Zerotape" applied, lapping well over the ends of the adjoining pipe covering. The fitting cover shall then be sealed with a trowel coat of Johns-Manville "Zeroseal" and finished with a brush coat of Johns-Manville "Zerogloss."

SEC. 11. *Procedure for application of corkboard to generator hatch covers.*—(See drawing 48N314.) The field-formed No. 20-gage metal strips shall be welded on 12- or 18-inch centers, depending on the width of the corkboard, to the underside of the generator hatch covers. The No. 12-gage soft iron wire studs shall also be welded on 6-inch centers to the underside of the generator hatch covers. The underside of the generator hatch cover shall then be cleaned and brushed free of all scale and painted one coat of Johns-Manville concrete primer.

The side of the rock corkboard to be placed on the underside of the hatch cover shall be dipped in hot asphalt, making sure that edges are dipped. The corkboard shall then be pressed in place allowing the iron wire studs to penetrate it, and the alternate metal tabs shall be bent over to hold the corkboard in place. Upon completion of placement of the corkboard the metal lath shall be placed over the corkboard and held in place by bending over the iron wire studs. After placement of the metal lath one coat of Johns-Manville concrete primer shall be applied. The entire insulated surface shall then be covered with two trowel coats of Eagle-Pitcher "Eagle Insulseal" coating of sufficient thickness to embed and completely cover the metal lath.

SEC. 12. *Painting.*—All insulated piping, ducts, and equipment shall be painted in accordance with the Authority's painting schedule. All bare copper pipe and tubing shall be thoroughly cleaned and painted with two coats of an approved waterproof lacquer.

CONSTRUCTION SPECIFICATION NO. BH20M-767—FOR APPLYING INSULATION TO MISCELLANEOUS PIPING SYSTEMS, BOONE PROJECT

(Reference drawings not included in this report)

SECTION 1. *Scope of work.*—This specification covers the application of insulating materials for various piping systems in the Boone powerhouse and control building.

The work covered by this specification is shown on the drawings listed in section 2. On each drawing the various pipelines to be covered are colored, with each color representing a different kind of insulation, as follows:

Color	System	Pipe insulation	Fitting insulation
Red	Cold water, drainage, and waste.	Felt antisweat	Built-up hairfelt and asbestos cement.
Green	Hot water	Asbestos corrugated paper	Asbestos insulating cement.
Brown	Chilled water	Fiberglas, or equal	Felted mineral wool.

SEC. 2. *Drawings.*—The drawings covered by this specification are:

47N410	47N507	47N557
47N411	47N550	47N558
47N415	47N551	47N600
47N416	47N552	47N601
47W422	47N553	47N650
47W423	47N555	47N651
47N505	47N556	47N831

SEC. 3. *Materials.*—The materials required for the insulation of the various piping systems shown on all the above drawings are listed on order lists Nos. BH20M-43 and BH20M-44.

SEC. 4. *General.*—Pipe, valves, fittings, and equipment shall have been tested, made tight, cleaned of all scale, rust, grease, dirt, or other foreign matter and made dry on the outer surface before any insulation is applied. Throughout the insulating procedure it is imperative that no water be admitted to the inside of the pipes or equipment being covered in order to avoid condensation on the exterior surfaces before completion of the installation. All valves shall be covered up to the bonnets only. Flanges shall be covered unless otherwise specified.

SEC. 5. *Procedure for insulating cold water, drainage, and waste pipe and fitting (red).*—This insulation, which is to prevent sweating, is 1 inch thick and furnished in 3-foot lengths. The outer layer shall be applied so as to stagger the joints on the inner layer. The longitudinal laps shall be sealed with asphaltic cement. Careful sealing of all joints is essential to prevent the entrance of moist vapor into the insulation. The pipe insulation is furnished with a canvas jacket and metal bands to hold this insulation in place. Bands shall be equally spaced to form a neat appearance. Cut out for pipe covering protection saddles where used on supports and pack the saddles with hairfelt; for other supports notch to clear or cover as required.

Valves, fittings, pump and strainers shall be covered with one layer of built-up hairfelt which is 1 inch thick and furnished in rolls 3 feet wide. The hairfelt shall be secured with a wrapping of binder twine, over which a double wrap of 2-inch-wide sealing tape shall be placed. A ¼-inch minimum thickness finish coat of asbestos cement shall be troweled on over the sealing tape. A canvas jacket shall be sewed on over each insulated fitting, valve, etc. Clamp bars on strainers need not be insulated.

SEC. 6. *Procedure for insulating hot water pipe and fittings (green).*—This insulation is furnished in 3-foot moulded sections, 1 inch thick, made of six

plies of preshrunk fine corrugated asbestos paper with canvas jacket and metal bands to hold this canvas in place. Install as a single layer and space bands equally to form a neat appearance.

The fittings for the hot water lines shall be covered with asbestos cement. A smooth hard finish shall be obtained. The cement shall be applied to a thickness equal to the adjacent insulation covering, making an overlap with the pipe insulation to present a neat appearance.

SEC. 7. *Procedure for insulating chilled water pipe, valves, and fittings (brown).*—This insulation is Fiberglas, or equal, molded insulation in 3-foot lengths. Pipes shall be supported on metal saddles placed over the insulation. This saddle shall be of galvanized iron sheet, not lighter than No. 18 gage, at least as long as the outside diameter of the insulation, extending halfway up each side, and snugly fitted under the line at each hanger point.

Before each length of insulation is applied, both longitudinal joints and one end surface shall be coated with Johns-Manville "Zeroseal," or equal, and the portion of pipe to be covered shall be painted with one coat of Johns-Manville "Zerogloss," or equal. Apply the insulation immediately to the freshly painted pipe, butting the coated end tightly against the uncoated end of the previously applied length, and placing so that longitudinal joints occur at the top and bottom of the pipe. The area to be covered by the waterproof lap shall be coated with Johns-Manville "Zeroseal," or equal, and the lap pressed smoothly into it. Seal the end joint with two plies of 3-inch-wide Johns-Manville "Zerotape," or equal, embedded in a coat of Johns-Manville "Zeroseal," or equal. Secure the insulation in place permanently with loops of soft iron wire spaced on 6-inch centers and finish with one brush coat of Johns-Manville "Zerogloss," or equal.

Before any fitting insulation is applied, the ends of the adjoining pipe insulation shall be freshly coated with Johns-Manville "Zeroseal," or equal. The fitting shall then be given one brush coat of Johns-Manville "Zerogloss" and wrapped with Johns-Manville "Zerotex," or equal, felted mineral wool until there is a sufficient quantity to shape into a fitting cover slightly thicker than the pipe insulation. The outer ply shall be extended about 1 inch over the end of the adjoining pipe insulation. The "Zerotex," or equal, shall be drawn down tightly over the fitting with jute twine and two layers of Johns-Manville "Zerotape," or equal, applied, lapping well over the ends of the adjoining pipe covering. The fitting cover shall then be sealed with a trowel coat of Johns-Manville "Zeroseal," or equal, and finished with one brush coat of Johns-Manville "Zerogloss," or equal.

SEC. 8. *Procedure for insulating refrigerant lines.*—The water chiller for the water chilling system shall be insulated with Johns-Manville "Rock-Cork" lagging shaped to fit the curvature of the chiller. The suction line shall be insulated with Johns-Manville molded "Rock-Cork" sectional pipe insulation. The suction line fittings shall be insulated with Johns-Manville "Zerotex" felted mineral wool. These materials are furnished with the water chiller by the York Corp. on requisition 666623, order C-51-26193.

The chiller insulation shall be applied in the same sequence and with the same materials as shown and detailed for the air-conditioning plenums on TVA drawing 47N821.

The suction pipe and fitting insulation shall be applied in the same manner and with the same materials as described in detail for the chilled water piping in section 7 of these specifications.

SEC. 9. *Painting.*—Refer to TVA Construction Specification No. G-14, Revised, for paint and painting. For color schemes refer to architectural color schedule.

CONSTRUCTION SPECIFICATION NO. G-11—FOR DISINFECTION OF WATER SYSTEMS, ALL PROJECTS

SECTION 1. *General.*—This specification covers the disinfection of water distribution systems, including mains, pipes, standpipes, tanks, and all other parts with which the water comes in contact. The requirements of this specification have been developed to conform with conditions peculiar to TVA policies and operations, and a section on bacteriological examination and approval is included to assure provision of a safe drinking water.

Disinfection is required as a public health safeguard after a potable water distribution system, including mains, tanks, or other appurtenances, has carried raw or polluted water, after completion of a new system, and after completion of maintenance or repair operations which may contaminate any part of the system.

Sec. 2. *Keeping the pipe clean.*—During the laying and jointing of the pipe, every practical precaution shall be taken to keep the interior of the pipe, fittings, and other accessories free from dirt and foreign matter. At times when laying is not in progress the open ends of the pipe shall be closed by a watertight plug, and joints of pipe shall be closed before the work is stopped. Joints which cannot be finished during a given working period shall be temporarily caulked with packing to make them substantially watertight.

Sec. 3. *Flushing.*—After the pressure test is completed and prior to chlorination the system, including mains, tank, or other appurtenances, shall be thoroughly flushed to remove any solids or sediment.

Sec. 4. *Chlorination of system.*—After flushing, all parts of the system with which water comes in contact shall be filled with a disinfecting mixture and left standing at least 24 hours or longer, as may be directed by the resident public health engineer. The amount of disinfecting solution shall be sufficient to produce a minimum chlorine residual of 100 parts per million at the time of filling. Following complete mixing of the disinfecting solution and the incoming water, the Drop Dilution Test or other approved method shall be utilized for determining the chlorine residual obtained on samples collected from representative points in the system, particularly at points remote from the point of chlorination. The minimum chlorine residual in all parts of the system at the end of the retention period shall be at least 25 parts per million.

Sec. 5. *Final flushing and test.*—At the end of the retention period and following a satisfactory test for residual chlorine, the mains, tanks, and other appurtenances shall be flushed throughout the full length with approved treated water.

Sec. 6. *Bacteriological samples.*—Following final flushing and filling of the system with approved treated water, two or more samples shall be properly collected in approved containers and submitted for bacteriological examination in accordance with instructions furnished by the resident public health engineer.

Sec. 7. *Placing in service.*—After at least two successive bacteriological examinations of samples, taken at intervals of not less than 24 hours, indicate negative bacteriological tests for coliform organisms, the resident public health engineer may issue approval for placing the system in service.

Sec. 8. *Repetition of procedure.*—Should the initial treatment fail to provide adequate disinfection and a safe drinking water, the disinfection procedure shall be repeated or modified by the resident public health engineer until such results are obtained.

As an alternative in special situations, use of the system may be approved, provided a minimum free chlorine residual of 1.0 parts per million is maintained continuously at the most distant point of significant use. Such chlorination shall be maintained until it is demonstrated that no further health hazard exists.

Sec. 9. *System undergoing maintenance or repair.*—Wherever possible, the procedure as described above shall be followed where a part of a system is undergoing maintenance or repair. The affected portion of the system shall be valved off, flushed, disinfected, flushed again, filled with approved treated water, and tested for bacteriological quality prior to placing in service.

However, it is recognized that there will be occasions when sufficient time is not available for following all the steps of this procedure. Frequently, at the time of a break, repair, or alteration to a main, service must be restored in a relatively short period of time. In such situations every practical precaution shall be taken to keep pipe and fittings clean, to flush thoroughly, and to utilize the most effective expedient for disinfection. Where disinfections as outlined above cannot be accomplished, the maintenance of a minimum free chlorine residual of 1.0 parts per million can be used as an alternative, if so directed by the resident public health engineer.

APPENDIX E

OPERATING INSTRUCTIONS

Appendix E includes a few of the typical operating instructions which are prepared by the Mechanical Design Branch for each individual project and issued to the operating and construction personnel in charge of the project. Drawings and exhibits referred to in these instructions are included in all copies of instructions issued, but they are not included herein. The instructions contained in this appendix are listed below:

OPERATING INSTRUCTIONS FOR POWERHOUSE, SPILLWAY AND SWITCHYARD OIL SYSTEMS, AND OIL-HANDLING EQUIPMENT AND SLUICE GATE OIL SYSTEM, BOONE PROJECT

(Reference drawings not included in this report)

INSULATING OIL-HANDLING AND PURIFICATION SYSTEM

General description

Refer to attached drawing 77N300 showing diagram of insulating oil system. All valves are normally closed.

The system consists of one 100-gallon-per-minute clean oil pump, one 100-gallon-per-minute dirty oil pump, and one 600-gallon-per-hour stationary oil purifier, fill and reject connections, connections for attaching a portable oil purifier to the system to replace the stationary oil purifier, all housed in the oil purication building at elevation 1331.17 and located at the southeast corner of the switchyard, and a complete piping system for oil supply to and return from all electrical equipment in the switchyard containing insulating oil. Adjacent to the building at elevation 1331, and included in the system, are 1 clean oil tank (11,600 gallons), and 1 dirty transformer oil tank (11,600 gallons), and 1 dirty circuit breaker oil tank (7,050 gallons).

All lines, except storage tank vent lines, should be kept full of oil at all times. Before being placed in service for the first time all lines shall be blown clean with compressed air.

IMPORTANT: Check relief valves on clean oil, dirty oil, and purifier pumps to make sure they open at the proper pressures; otherwise motor may be overloaded.

Purifier operation shall be as directed in the manufacturer's instruction book. The purifier is equipped with inlet and outlet pumps.

Drain valves T–76, T–78, and T–80 from bottom of storage tanks are used only for cleaning out the tanks.

The vent and overflow from each tank is open to atmosphere and any overflow will be wasted.

No dirty oil can pass into the supply header or mix with clean oil; dirty oil must pass through the purifier or go directly to the dirty tank.

Hose operations are similar to those illustrated on TVA detail drawing 77W203 (not included). The system fill and reject connections have female iron pipe threads, and any connecting male hose ends must have threads to match.

NINE DIFFERENT OPERATIONS may be performed as follows:

1. *Filling either dirty oil tank from fill connection, using dirty oil pump*

Oil will be received through the system fill connection at the manifold piping in the oil purification building. Open valves T–13, T–2, T–4, and appropriate valve T–6 or T–8, and operate dirty oil pump.

2. *Purifying oil from either dirty tank and transferring to clean tank, using purifier pumps*

For transformer oil, open valves T–10, T–16, T–1, and T–5 and operate purifier.

For circuit breaker oil, open valves T–12, T–16, T–1, and T–5 and operate purifier.

3. *Flushing headers with clean oil, using clean oil pump*

Before filling any electrical equipment, the supply header must be flushed with clean oil. Open valves T–7, T–9, T–11, T–15, sectionalizing valves as required to reach valve box in use, T–24, and proper tank valve T–10 or T–12. Connect 3-inch drain hose valve and 1½-inch fill hose valve (in valve box being used) with 3-inch drain hose, using 3- by 1½-inch bushing. Open hose valves and circulate clean oil, using clean oil pump, until an oil sample at valve box tests satisfactorily.

4. *Filling electrical equipment from clean tank, using clean oil pump*

Perform operation No. 3. After flushing headers, close fill and drain valves in valve box and remove 3-inch drain hose. Connect 1½-inch fill hose between 1½-inch fill hose valve in valve box and fill valve on equipment, open 1½-inch fill valve in valve box and fill valve on equipment, and operate clean oil pump until desired oil level is reached.

5. *Draining electrical equipment into the appropriate dirty tank, using dirty oil pump*

Connect 3-inch drain hose between drain valve in valve box and equipment drain valve. Open equipment drain valve, drain valve in valve box, and the appropriate drain header sectionalizing valve. Open valves T–24, T–2, T–4, and proper tank valve T–6 or T–8. Operate dirty oil pump until equipment is empty.

6. *Purifying oil in electrical equipment by circulating through purifier.*

Connect 1½-inch fill hose and 3-inch drain hose to their respective valves on equipment and in valve box. Open valves at hose ends and the appropriate sectionalizing valve in supply and drain headers. Open valves T–24, T–16, T–1, and T–15 and operate purifier until an oil sample taken at sampling valve on equipment tests satisfactorily.

7. *Circulating oil in any tank through purifier*

Select tank. Open appropriate tank valves T–5 and T–7, T–8 and T–10, or T–6 and T–12. Open valves T–16 and T–1, operate purifier until sample tests satisfactorily.

8. *Using portable purifying equipment for yard service*

A portable purifier may be used by connecting directly to equipment fill and drain valves, using fill and drain hose, or may be used in place of the stationary purifier by connecting fill and drain hose to valves T–3 and T–18. If portable purifier is used as replacement for stationary purifier, follow procedures outlined for operation No. 6 except open valves T–18 and T–3 in place of valves T–16 and T–1.

9. *Removing oil from system, using appropriate pump*

Oil unfit for further use may be discharged from either dirty tank into receiving equipment at the system reject connection, using the 3-inch drain hose and operating the dirty oil pump. Open appropriate tank drain valve T–10 or T–12, T–2, T–4, and T–14, and operate dirty oil pump. Note that the

dirty oil pump will fill an oil drum in approximately one-half minute unless its discharge valve is throttled and part of the flow is circulated around the pump through its relief valve.

If it is desired to remove any filtered oil from the system, connect the fill and reject connections at the manifold piping with 3-inch drain hose. Open valves T–7, T–9, T–11, T–14, T–13, and either dirty oil tank valve T–10 or T–12. Operate clean oil pump for approximately two minutes to flush line and hose. After flushing, close valves T–13 and T–14, disconnect one end of drain hose from fill connection, reopen valve T–14, and operate clean oil pump to remove desired quantity of filtered oil. Note that the clean oil pump will fill an oil drum in approximately one-half minute unless its discharge valve is throttled and part of the flow is circulated around the pump through its relief valve.

In an emergency the stationary purifier pumps may be used for removing dirty or clean oil from the system through the reject connection.

Note: Return all valves to their normally closed positions after completion of each operation.

GOVERNOR AND LUBRICATING OIL-HANDLING AND PURIFICATION SYSTEM

General description

Refer to the attached drawing 47N301 showing diagram of the governor and lubricating oil system.

The system consists of 1 clean oil tank and 1 dirty oil tank, each of 2,125-gallon capacity, one 33.5-gallon-per-minute clean oil pump, one 33.5-gallon-per-minute dirty oil pump, one 375-gallon-per-hour purifier, all located in the powerhouse service bay at elevation 1269; a complete piping system for supply to and return from the governors, main unit turbine guide bearings, and generator thrust and guide bearings; two 6-gallon-per-minute pumps in each turbine pit for circulating oil to turbine bearing or draining turbine bearing sump to dirty oil tank; and a fill and reject box located in a valve recess is the service bay deck at elevation 1302 near the entrance to the storage room.

IMPORTANT: Oil must be kept free from any dirt, grit, scale, chips, wood, waste, cloth, or other foreign matter injurious to bearings and governor equipment. Before placing lines in service blow out with compressed air and thoroughly flush all supply lines with thin oil.

IMPORTANT: Check relief valves on clean oil, dirty oil, and purifier pumps to make sure they open at the proper pressures.

The drain header and valves between the overflow from the generator thrust and guide bearing and the dirty oil tank must normally be kept open to allow any overflow to flow by gravity into the dirty oil tank.

All valves of the system should be kept normally in the position (open or closed) indicated on the diagram.

Drain valves GO–14 and GO–16 at the bottom of the tanks are used only for cleaning out the tanks.

The combined vent and overflow from each tank leads to the floor drainage system and the station sump. Any overflow will be wasted.

No dirty oil can pass into the supply header or mix with clean oil.

Purifier operation shall be as directed in the manufacturer's instruction book. The purifier is equipped with inlet and outlet pumps.

It is intended that oil be purified in batches. A generator bearing or governor sump tank should be drained (only if the unit is shut down) into the dirty tank and then refilled with clean oil from the clean tank.

Oil for machinery oil cans may be obtained from gage glass petcocks on clean oil tank.

The system fill and reject box has female iron pipe threads, and any connecting male hose end must have threads to match.

ELEVEN DIFFERENT OPERATIONS may be performed with valves in normal positions except as noted. Return all valves to normal positions when an operation is completed. Valves 1GO–8, 2GO–8, 3GO–8, 1GO–14, 2GO–14, 3GO–14, GO–12, GO–4, and GO–2 *must always be open* when units are operating. Operations are as follows:

1. *Filling either tank from outside fill box, using clean oil pump*

Oil will be received through hose connection at system fill and reject box on the service bay deck at elevation 1302. To fill clean oil tank, make sure

three-way valves GO–15 and GO–17 are in their correct nomal setting, open valves GO–19, GO–11, GO–13, and GO–3, and operate clean oil pump.

To fill dirty oil tank, make sure three-way valves GO–15 and GO–17 are in their correct normal setting, open valves GO–19, GO–11, GO–13, and GO–5, and operate clean oil pump.

2. *Filling clean oil tank from outside fill box through purifier*

Close valves GO–12 and GO–4, set three-way valve GO–17 to position shown on diagram, open valves GO–19, GO–6, GO–1, and GO–3, and operate purifier. When operation is completed immediately reopen valves GO–12 and GO–4 permitting overflow from generator thrust and guide bearing to flow into the dirty tank.

3. *Purifying oil from dirty oil tank and transferring to clean oil tank, using purifier*

Close valve GO–12, open valves GO–6, GO–1, and GO–3, and operate purifier. When operation is completed immediately reopen valve GO–12.

4. *Flushing headers with clean oil, using clean oil pump*

To flush lines to any generator bearing, close appropriate overflow valve 1GO–8, 2GO–8, or 3GO–8; open valves GO–7, GO–9, GO–11, GO–13, GO–21, and appropriate valves 1GO–7, 2GO–7, or 3GO–7, and 1GO–10, 2GO–10, or 3GO–10. Operate clean oil pump to transfer oil from clean tank to dirty tank for a period of 5 to 10 minutes. After flushing, immediately reopen generator bearing overflow valve 1GO–8, 2GO–8, or 3GO–8. To flush headers before filling any turbine bearing, open valves GO–7, GO–9, GO–11, GO–13, GO–21, and GO–23. Operate clean oil pump to transfer oil from clean tank to dirty tank for a period of five to ten minutes.

5. *Filling governor sump tank, using clean oil pump*

Flush sump tank with clean oil by opening valves GO–7, GO–9, GO–11, GO–13, GO–21, and appropriate valves 1GO–1, 2GO–1, or 3GO–1, and 1GO–18, 2GO–18, or 3GO–18, and operating clean oil pump to transfer oil from clean tank through governor sump to dirty tank for a period of 5 to 10 minutes; then close appropriate valve 1GO–18, 2GO–18, or 3GO–18 and fill sump tank to proper level as indicated on gauge located on front of actuator cabinet.

6. *Filling generator bearing, using clean oil pump*

The operation described is for unit 1. Operation for other units will be similar by using correspondingly numbered valves.

Flush headers as in operation No. 4, and then close valves 1GO–7 and 1GO–10. Clean the oil filter on the supply line by giving the handle one complete turn. Open valves 1GO–3, 1GO–5, and 1GO–9, and operate clean oil pump until the bearing reservoir is filled to the proper level on the gauge. When operation is completed, observe the sight flows to check the tightness of the closed valves 1GO–6, 1GO–9, and 1GO–10.

7. *Filling turbine bearing sump tank, using clean oil pump*

The operation described is for unit 1. Operation for other units will be similar by using correspondingly numbered valves.

Flush headers as in operation No. 4, and then close valve GO–23. Open valves 1GO–11 and 1GO–13 and operate clean oil pump until sump tank is filled to proper level as indicated on the gauge.

8. *Draining governor sump and pressure tanks, using dirty oil pump*

The operation described is for unit 1. Operation for other units will be similar by using correspondingly numbered valves.

Unit will be shut down.

To drain the governor oil sump, open valves 1GO–18, GO–8, GO–10, and GO–5, close valve GO–4, and operate dirty oil pump until sump is empty. After draining the sump, immediately reopen valve GO–4. In the case of either unit 2 or unit 3, proper care must be taken at the twin governor actuator cabinet to see that the sectionalizing valve between the two sumps is closed (see governor instructions) before starting the operation.

To drain the governor pressure tank, first take care to blow off air pressure in the tank and close isolating valve between pressure tank and actuator (see governor instructions). Open valves 1GO–20, GO–8, GO–10, and GO–5, close valve GO–4, and operate dirty oil pump until tank is empty. After draining tank immediately reopen valve GO–4.

9. *Draining generator bearing, using dirty oil pump*

The operation described is for unit 1. Operation for other units will be similar by using correspondingly numbered valves.

Unit will be shut down.

Open valves 1GO–6, GO–8, GO–10, and GO–5, close valve GO–4, and operate dirty oil pump until bearing reservoir is empty as shown by drain line sight flow. After draining reservoir immediately reopen valve GO–4.

10. *Draining turbine bearing sump tank, using circulating pump in turbine pit*

The operation described is for unit 1. Operation for other units will be similar by using correspondingly numbered valves.

Unit will be shut down.

Close valve 1GO–15, open valves 1GO–2 and 1GO–4, and operate alternating-current circulating pump in pit until sump tank is empty as shown on the tank level indicator.

11. *Removing oil from system*

Oil unfit for further use may be discharged from the dirty tank into drums or other receiving equipment at the fill and reject box located in the service bay deck at elevation 1302, using the dirty oil pump. Set 3-way valve GO–15 to position shown on diagram and check 3-way valve GO–17 for correct normal setting. Open valves GO–8, GO–10, and GO–19, close valve GO–12, and operate dirty oil pump until dirty tank is empty. After emptying dirty tank immediately reopen valve GO–12.

In an emergency the purifier pumps may be used to remove dirty oil from the system through the fill and reject box by opening valves GO–1 and GO–6 in place of valves GO–8 and GO–10. If it is desired to remove any filtered oil from the system, oil may be pumped from the clean oil tank to the fill and reject box using the clean oil pump. Set three-way valve GO–15 to position shown on diagram and check three-way valve GO–17 for correct normal setting. Open valves GO–7, GO–9, GO–11, GO–13, and GO–19, and operate clean oil pumps.

Note: All valves are to be restored to their normal open or closed positions as shown on Valve Operation Diagram 47N301 on completion of each operation.

SLUICE GATES OIL PRESSURE SYSTEM

General description

Refer to attached drawing 47N300 showing valve operation diagram of sluice gates oil pressure system.

The system consists of 2 cylinders, 1 for the service gate and 1 for the emergency gate; one 20-gallon-per-minute high-pressure oil pump; one 330-gallon oil storage tank; and a complete piping system for supply to and return from the operating cylinders. The cylinders are direct-connected to the sluice gates and are located in the spillway operating gallery at elevation 1280. The oil pump and storage tank are located in the pump chamber in this gallery at the same elevation.

IMPORTANT: Oil must be kept free from all dirt, grit, scale, chips, wood, waste, cloth, or other foreign matter injurious to equipment. Before placing lines in service for the first time, blow out with compressed air and thoroughly flush all lines with thin oil.

IMPORTANT: Check relief valves on the pump to make sure they open at the proper pressures.

All valves of the system must be kept normally in the position (open or closed) indicated on the diagram.

The vent lines from the operating cylinders lead through a sight flow funnel to a gutter and any oil vented will be wasted.

Drain valve SO–4 at the bottom of the tank is used only for cleaning out tank and should be kept closed.

The system fill valve SO–3 has 1½-inch female iron pipe threads, and any connecting hose must have threads to match.

The whole system, including storage tank, holds approximately 810 gallons of oil.

Gates shall always be fully open or closed—never operate at partial opening.

THREE DIFFERENT OPERATIONS may be performed with valves in normal positions except as noted. Return all valves to normal positions when an operation is completed. Operations are as follows:

1. *Filling system with new oil*

Gates are assumed to be initially in the lowered position.

On top of each cylinder there is a ¼-inch tap which is normally plugged. In the filling operation these plugs should be removed and laid aside ready to be replaced as directed. Close valve SO–1, connect source of supply to fill valve SO–3, and open valve SO–3. Open shutoff valve SO–5 and close regulating valve SO–2. Set directional 4-way valve SO–7 to the lowering position (handle in horizontal position to right) which allows oil to enter cylinders near top. Open valves SO–9, SO–11, SO–13, and SO–15. Start the pump and continue pumping operation until oil is vented from the ¼-inch taps in the cylinder heads, then closing valve SO–11 as the service gate cylinder is filled and valve SO–15 as the emergency gate cylinder is filled. Replace ¼-inch plugs in operating cylinder heads. Close shutoff valve SO–5, set four-way valve SO–7 to raising position (handle down in vertical position), open the four permanent vent valves from the cylinders, and reopen shutoff valve SO–5 to fill lines to bottom of cylinders until oil is vented through funnel. Close valves SO–9 and SO–13 and then close the permanent vent valves.

The storage tank should now be filled to its 300-gallon level. Open regulating valve SO–2 and continue pumping until desired level in tank is reached. Stop the pump and close shutoff valve SO–5. Close fill valve SO–3, disconnect oil supply, and reopen valve SO–1.

2. *Raising gate*

The operation described is for raising the service gate.

a. Set directional four-way valve SO–7 to raising position (handle down in vertical position).
b. Open shutoff valve SO–5 and make sure that regulating valve SO–2 is open.
c. Open valves SO–9 and SO–11.
d. Start pump.
e. Throttle regulating valve SO–2 until pressure gage shows a sudden pressure rise indicating gate has reached full open position.
f. Open regulating valve SO–2 and close valves SO–9 and SO–11. Stop the pump.
g. Close shutoff valve SO–5.

The emergency gate is raised in an identical procedure except that in operation (c) above the valves SO–13 and SO–15 are opened instead of valves SO–9 and SO–11.

3. *Lowering gate*

When gates are in full open position a semiautomatic gate hanger must be released before lowering gate. This gate hanger consists of a latch arrangement which engages the enlarged end of the gate stem extension in its raised position. A cable with a spring section and welded ring on lower end is attached to the latch arrangement. To release this gate hanger pull the cable ring down and place on hook anchor on lower flange of operating cylinder. The expanded spring section is then ready to open the latch arrangement. Raise the gate slightly (operation 2) to permit the latch arrangement to open, then follow the outlined procedure for lowering the gate. In an emergency the gate may be lowered without releasing the hanger, thus breaking the renewable safety stud. The operation described is for lowering the service gate.

a. Set four-way valve SO–7 to the lowering position (handle in horizontal position to right).
b. Open shutoff valve SO–5 and make sure the regulating valve SO–2 is open.
c. Open valves SO–9 and SO–11.
d. Start pump.
e. Throttle regulating valve SO–2 until pressure gage shows a sudden pressure rise indicating gate has reached the fully closed position.
f. Open regulating valve SO–2 and close valves SO–9 and SO–11. Stop pump.
g. Close shutoff valve SO–5.

The emergency gate is lowered in an identical procedure except that in operation (c) above the valves SO–13 and SO–15 are opened instead of valves SO–9 and SO–11.

OPERATING INSTRUCTIONS FOR POWERHOUSE UNWATERING, FILLING, AND DRAINAGE SYSTEMS, BOONE PROJECT

(Reference drawings not included in this report)

UNWATERING, FILLING, AND DRAINAGE SYSTEM

Unwatering unit 1 scroll case and draft tube

Refer to attached drawing 47N302.

The unwatering and station drainage sump is located below the air compressor and pump room floor of the service bay and is serviced for scroll case and draft tube unwatering by two 3,000-gallon-per-minute pumps, of the vertical turbine type, with 60-horsepower vertical motors located on the air compressor and pump room floor at elevation 1269. These pumps are manually operated.

Procedure

a. Lower intake head gates.

b. Open wicket gates and scroll case drain valve 1U–4, located in the draft tube access gallery at elevation 1250, allowing water in the unit to come to tailwater level.

c. Lower draft tube gates.

d. Open draft tube drain valve 1U–2, using floorstand near the two 3,000-gallon-per-minute pumps at the station sump in the service bay at elevation 1269.

e. Immediately start No. 3 unwatering pump (3,000 gallons per minute). Use No. 4 unwatering pump (3,000 gallons per minute) as a standby.

f. If the unit is being unwatered for underwheel inspection or repair, a petcock installed in the access mandoor to the draft tube shall be opened to check the water level in the draft tube before opening the mandoor.

g. Stop pump after water has reached the desired elevation in the unit.

Filling unit 1 scroll case and draft tube

Procedure

Note: Never raise intake head gates until draft tube gates are raised.

h. Close draft tube drain valve 1U–2 (d above) and scroll case drain valve 1U–4 (b above).

i. Open fill valve 1U–1 located in the draft tube access gallery at elevation 1250.

j. When water in the unit has reached tailwater elevation the upstream and downstream pressures on the draft tube gates are balanced and the draft tube gates may be raised.

k. Close wicket gates and fill valve 1U–1 (i above).

l. Raise head gates, completely filling the unit.

Note: If required, both 3,000-gallon-per-minute pumps may be operated simultaneously to unwater a unit. With tailwater at elevation 1265.6 (8,000 cubic feet per second), one pump will unwater a unit in approximately 1 hour, and when filling a unit water will rise to that level in approximately 15 minutes.

Operation for units 2 and 3

The operations for unwatering and filling units 2 and 3 are identical to those for unit 1, using corresponding valves.

Operation of station drainage system

The unwatering and station drainage sump is located below the air compressor and pump room floor of the service bay and is serviced for station drainage by two 300-gallon-per-minute pumps of the vertical turbine type, with 10-horsepower vertical motors located on the air compressor and pump room floor at elevation 1269. These two pumps are operated automatically by floats and start and stop at the levels indicated on the operation diagram (refer to pump No. 1 and pump No. 2).

Should the two 300-gallon-per-minute pumps be unable to handle the volume of water entering the sump an alarm will ring in the control building when the water reaches elevation 1247, notifying the operator to start one of the 3,000-gallon-per-minute unwatering pumps. Should the situation demand it, the second 3,000-gallon-per-minute pump may also be started, thus allowing all four pumps to be used in the event of a condition requiring excessive drainage capacity.

To permit servicing of the 300-gallon-per-minute station drainage pumps without pulling them from the well, the sump water level may be lowered by using one 3,000-gallon-per-minute unwatering pump.

OPERATING INSTRUCTIONS FOR WATER TREATMENT PLANT, BOONE CONTROL BUILDING

(Reference drawings not included in this report)

GENERAL

The water-treatment plant located in the control building serves the potable water demands of the project. It is estimated that the maximum demand will be 1,500 gallons per day. The nominal capacity of the filters is 12.6 gallons per minute although less floc carryover from the settling tank will be experienced if the plant is operated at between 8 and 10 gallons per minute. While the mechanical features of the plant are designed to operate automatically, the plant cannot accomplish its purpose of providing *clean, safe* water without a certain amount of mechanical control and supervision. Routine operations will include washing the filters, blowing down the settling tank, making up chemical solutions, and checking the operation of the plant by visual examination and chemical tests followed by the adjustment of chemical dosages and mechanical controls necessary to correct any unsatisfactory conditions which may have been observed. Such examination and tests should be made as often as necessary to obtain safe water, but under normal conditions the plant should receive daily attention. The service pumps are controlled by a float switch on the storage tank in the basement of the visitors' building, with a cutout switch for low level in the clearwell at the control building. The raw water supply is controlled by a balanced float valve set to close at elevation 1325.19 in the settling tank. The chemical solution feeders and chlorinators are controlled by a float switch on the clearwell. The following instructions refer to the several pieces of equipment in the treatment plant, which may be found by referring to detail drawings 47N555, 47N556, 47N557, and 47N558 (not included in these instructions). Valves referred to by number are shown on Valve Operation Diagram 47N306, which is part of these instructions.

RAW WATER

Supply

The raw water will normally be obtained from 1 of the 4 raw water intakes in the forebay at a maximum pressure of 25 pounds per square inch. For operation of the treatment plant during periods of low headwater, when insufficient pressure may be available for gravity flow from the forebay, the raw water supply three-way valve R–9 may be set to obtain water from fire and service storage tank at a pressure of about 55 pounds per square inch.

Quality

The raw water quality may be controlled to some extent by using a raw water intake at which the best results may be obtained in the treatment plant. The operator should use care in selecting a raw water intake valve in the powerhouse which will draw the supply from not too near the surface and also not too deep in stagnant water. For initial operation select an intake about 10 or 15 feet below headwater level. The quality will vary considerably, depending on the manner in which water is discharged from the South Holston and Watauga Reservoirs. With sluice conduits discharging, very turbid water will have to be treated. When generating units are in service, relatively clear water will enter the treatment plant. These changes in quality will affect the amounts of chemicals required for optimum flocculation and settling. Jar tests only will determine the correct chemical dosages to be used.

Controls

The raw water supply enters the mixing tank at atmospheric pressure. The supply is controlled by a float valve set to close at an elevation of 1325.19 in the settling tank.

CHEMICAL FEEDERS

General

There are five diaphragm pump-type chemical solution feeders in the water-treatment room, and the materials of which they are constructed make them suitable for feeding any chemical normally used in water treatment, except ammonia.

All five chemical feeders are identical except for the discharge hose. Two feeds include 25 feet of ⅜-inch rubber discharge hose equipped with injection nozzles to be used to feed the hypochlorite and post-alkali solutions into the effluent line from the filters at a pressure not exceeding 3 pounds per square inch. The other 3 feeders are equipped with 15 feet of ⅜-inch rubber discharge hose without injection nozzles, 2 of which are used as alkali and coagulant solution feeders, the third being a standby unit for any of the other four units in the plant.

The hypochlorite solution feeder is used to sterilize the filtered water. The post-alkali solution feeder is used for feeding either soda ash to react with the CO_2 and thus produce a less corrosive water or for feeding Calgon which will also stabilize the filtered water. This post-alkali feeder may or may not be needed, depending upon the pH of the filtered water. When not required, this unit will be a standby for the hypochlorite feeder.

The coagulant solution feeder is used for feeding a solution of aluminum sulphate or filter alum to the mixing tank. The alkali solution feeder is used for feeding soda ash or alkali. These two chemicals react to form the floc necessary for coagulation in the settling tank.

Chemical feeding

All chemicals are fed in solution, the strengths of which must not exceed the following:

Chemical	*Percent Solution*
Hypochlorite	1.0
Aluminum sulfate	Saturated
Soda ash	Saturated
Calgon	Saturated

Ten-gallon earthenware crocks are provided for mixing and holding these solutions. The alum and soda ash will dissolve more readily in hot water which may be obtained from the sink in the battery room for this purpose.

Each feeder has a stroke length adjustment by which the quantity of solution may be varied. This adjustment may be made by means of a double eccentric cam with indicating scale on the side of the pump so that each increment of movement on the scale will provide equal increments of chemical delivery. The strength of solution may also be varied to give a further method of varying the quantity of chemical.

A sight glass is installed on the suction hose in which the flow of solution can be observed. This should be regularly inspected, for occasionally the suction and discharge check valves in the pump head stick, resulting in reduced or no flow. When stoppage occurs the pump head can be removed and the rubber valves and seats cleaned or replaced. The manufacturer's operating instructions should also be followed. The pump head is molded of a transparent plastic material to enable the operator to observe the action of check valves and diaphragm while pump is operating.

CHEMICAL CONTROL

Coagulants

The purpose of adding chemicals is to produce particles of floc in the water to which the dirt, turbidity, color, and bacteria cling and which are settled out in the settling tank, with some carryover to the filters to form a thin mat on top of the sand layer in the filters. The coagulant here used is aluminum

sulphate which combines with the natural alkalinity in the water and with the soda ash, all of which are soluble, to form the insoluble aluminum hydrate or floc. Theoretically about one-half part of alkali is required to react with one part of alum in pure distilled water. However, due to the existence of other chemical compounds in natural waters, this relation will vary and the exact ratio can only be determined by test on the water in question. The reaction between the alum and alkali produces not only the floc but also CO_2 which reduces the pH and makes the water corrosive. If too much alum is used, the excess will remain in a soluble state and pass through the filters. Alum is very corrosive and with the CO_2 will attack the piping in the powerhouse system, causing rust and "red water" troubles. If too much alkali is used, it will redissolve some of the floc or keep it in such fine particles that it will pass through the filters and produce a smoky appearance in the final water.

Post-alkali feed

As indicated above, the pH of the filtered water will be reduced by the generation of CO_2 in the chemical reaction during floc formation. This will make a corrosive water. The addition of an alkali such as soda ash reacts with the carbonic acid to form calcium bicarbonate. This is soluble and increases the hardness of the water, but the pH is increased and the water is less corrosive. The operator must run alkalinity and pH tests of the water in the clearwell and regulate the post-alkali feeder so that a stable water is produced. Exhibit A of these instructions shows the relation between pH and alkalinity necessary to produce a stable water. For this plant, if the lower of the three curves shown is reached, the water should be considered satisfactory.

Another method of stabilizing the water is by the introduction of sodium hexametaphosphate, sold under the trade name of Calgon. There is some doubt as to the chemical reactions involved in this process. However, very small amounts of this material produce a stable water. From 1 to 2 parts per million should suffice in this plant.

MIXING TANK

General

The mixing tank is 2 feet 6 inches in diameter and about 10 feet 3 inches high. The raw water enters at the top of this tank when chemical solutions of the coagulant and alkali are administered. The discharge from the raw water line is directed along the inside edge of the tank to produce a swirling or spiral motion. The mixture passes out of the bottom of the tank through the annular space between the lower edge and the foundation into the settling tank. The mixing tank capacity is about 350 gallons, giving a retention period of 28 minutes for a flow of 12.6 gallons per minute. The purpose of the tank is to provide agitation to mix the chemicals thoroughly with the water and to provide time for a chemical reaction to take place between the alum and alkali and form a floc. The smallest amount of chemical which will produce a settleable floc should be used, not only for economy but for reasons previously described.

The mixing tank and settling tank are concentric and have a common drain valve FP–12. The raw water inlet to the mixing tank is controlled by a float valve set to close at a water surface elevation of 1325.19 in the settling tank. For cleaning the mixing tank refer to cleaning of the settling tank.

SETTLING TANK

General

The settling tank has a total effective capacity of about 2,700 gallons and a retention period of 3½ hours at a 12.6-gallon-per-minute rate. This tank is of the upward-flow type. Water enters at the bottom through the annular space at the bottom of the mixing tank and is distributed evenly over the bottom area. The chemically treated and mixed water rises vertically to the surface at a velocity of about 2¼ feet per hour at a plant rate of 12.6 gallons per minute. The heavy particles of floc will settle to the bottom, carrying with them the adsorbed bacteria and turbidity. The clear water is collected at the surface in a launder from where it flows by gravity to the filters. An overflow to the control building sump is provided on this tank.

Cleaning

A blanket of sludge will form on the bottom of the settling tank composed of the floc and settled material from the raw water and will further aid clarification. The surface of this blanket is clearly seen when the plant is not in operation. This blanket should be maintained at a depth of about 12 inches. About once a week a portion of this blanket should be removed by blowing down the tank after the sludge has settled, preferably just before starting a filter run. To blow down, open drain valve FP–12 which will rapidly lower the elevation in the mixing tank and produce a differential head between the settling and mixing tanks. This will produce a high velocity flow from the settling tank through the annular space at the bottom of the mixing tank and carry part of the sludge through the drain to the control building sump. Drawing the water level in the settling tank down about 12 inches once a week should maintain a proper sludge blanket. However, this can be determined only by operating experience.

About once a year the drain valve FP–12 should be opened and both mixing and settling tanks completely flushed out. The filter effluent valves FP–5 and FP–7 should be closed and all chemical solution feeders stopped during this flushing operation. This should also be done in the event the sludge becomes septic. Overflow and drainage water will discharge to the control building sump and thence to tailrace.

FILTERS

General

The two gravity-type filters contain a manifold strainer system at the bottom covered with graded layers of gravel with a 2-foot layer of filter sand on top. The maximum capacity is 6.3 gallons per minute each and should never be exceeded without permission from the public health engineer.

Controls

The settled water is piped to the filter through the funnel above the filter sand. The water then travels down through the sand, gravel, and manifold and out to the clearwell. The rate of flow to the filter is automatically controlled by the differential head existing between the surface in the launder of the settling tank and the surface in the filter, the filter surface being maintained by the rate-of-flow indicators. The effluent rate of flow is indicated on the flow indicators in the effluent lines from each filter. It is important that this rate not exceed 6.3 gallons per minute. With low level in the clearwell and a water surface elevation 1324.32 in each clean filter, the effluent globe valves FP–9 and FP–11 should be throttled and the handwheels removed when this flow is reached. A loss-of-head gage is provided on the effluent line from one of the filters. When the filters are clean the differential head between the water surface in the filter and the level in the gage should be about 1 foot. This should be considered zero loss. As the filter becomes dirty, the loss of head will gradually increase. When this differential head reaches a point where the level is no longer visible in the loss-of-head gage, or about 4 feet below zero loss, the filters should be washed. If the loss of head is permitted to build up to where the level is no longer visible, the sand layer will no longer support the layer of floc and dirt particles on the filter surface, and the water will break through this layer, short-circuiting the flow and carrying dirt down into the filter bed. This will not only cause a reduction in the quality of treated water but will seriously affect the future operation of the filters by forming mud balls in the sand layer.

Operation

Normally the filters will go into operation automatically when the level in the filters exceeds the level in the clearwell. The influent and effluent valves FP–1, FP–3, FP–5, and FP–7 must be open and the filter to waste valves FP–6 and FP–8 closed. If the filters have been shut down for repairs or inspection, they should be filled with water from the bottom through the underdrain system and washed before being put back into service. Water must never be permitted to fall directly on the sand surface.

Inspection

To inspect the filters, close filter influent valves FP–1 and FP–3; immediately stop all chemical solution feeders; close effluent valves FP–5 and FP–7;

partially open the filter to waste valve FP–6 or FP–8; and draw the water level in each filter down below the sand level. A dirty floc should present a smooth, even, unbroken layer on the sand surface. If craters, cracks, or mud balls are found, it is evidence of either insufficient washing or too long a run between washings. If any of these conditions are found, they should be corrected. Mud balls should be removed. Filters should be washed for a longer period or at a slightly higher rate and at the time when the loss of head through the filters during filtering is somewhat less than the differential pressure previously indicated. After washing, the sand surface should be level, even, with no evidence of mud balls; the sand should be composed of individual grains with none cemented together; the grains may be discolored but should be free from any surface coatings. The top of the sand should be about 24 inches down from the top edge of the influent funnel.

WASHING FILTERS

General

When the loss of head at filtering reaches the point where washing is necessary, the plant should be shut down and each filter washed separately. In washing, the direction of flow is reversed to that in filtering, that is, water is brought into the manifold at the bottom of the filter from which it rises up through the gravel and sand and carries the dirt on top of the sand out to the waste drain.

Controls

Water for washing is obtained from the wash water storage tank located in the file room at elevation 1342.19. This storage tank is filled from the distribution system through a gate valve FP–19 which must be cracked open so as to fill the tank in about 24 hours during filtering operation. The supply to the storage tank is stopped by a float valve when the level reaches elevation 1352.5. An overflow to the control building drainage system is provided.

It is important that the wash water rate of flow to either filter not exceed 47 gallons per minute. This shall be accomplished by throttling valve FP–29 on the wash waterline and removing the handwheel when this flow, as indicated on the wash water flow indicator, is reached. A bypass valve FP–27 is provided for this flow indicator and could be used if the flow indicator should be removed for testing or repair. The wash waterline is connected to the common filter effluent and backwash line of each filter through valves FP–31 and FP–33 which will be either closed during filtering operations or wide open during washing.

Operation

To wash a filter the whole treatment plant should be shut down, including the chemical solution feeders, and all valves (FP–1, FP–3, FP–5, and FP–7) on both filters closed. Then close the loss-of-head gage valve FP–13. Open wash water to waste valve FP–2; then slowly open the filter wash water valve FP–31, and check the wash water flow indicator to make sure the rate of flow does not exceed 47 gallons per minute. Dirty wash water will rise in the filter to the level of the influent funnel, which now becomes the wash water trough, and then down the waste pipe into the control building sump and drain to tailrace. The filter washing should be continued until only clear water, as observed in the filter, is discharged, but for not less than 5 minutes. After washing, close the wash water inlet valve FP–31 and the wash water to waste valve FP–2. Then open the wash water to waste valve FP–4 on the other filter, slowly open its wash water valve FP–33, and proceed with washing the second filter. After both filters have been washed, close all valves (FP–33 and FP–4) at the filiters. Then *partially* open the filter to waste valves FP–6 and FP–8 and open both filter influent valves FP–1 and FP–3. Immediately place the alkali and coagulant chemical solution feeders back in operation. Allow the filter effluent to drain to the sump for a period of 2 or 3 minutes in order to allow a film of floc to be formed on the filter sand. Care should be taken in opening the filter to waste valves so that the maximum filter capacity of 6.3 gallons per minute is not exceeded. The filters are now ready to be put in service. Close filter to waste valves FP–6 and FP–8, open the loss-of-head gage valve FP–13, open the filter effluent valves FP–5 and FP–7, and immediately place the hypochlorite and post-alkali chemical solution feeders back in operation.

The purpose of washing is to so agitate the sand layer that as the individual sand grains collide and rub together all foreign matter is removed and carried out to waste. The relatively high upward flow of water expands the sand layer to preferably 130 percent of its normal depth. It is evident that a higher wash rate will be required to expand a large-grained sand than a fine sand. Likewise, a higher rate is required of warm water than cold water to produce equal expansion of the same-sized sand. When first washed some very fine sand will be carried out to waste. However, after the first 2 or 3 washings, no appreciable amount of sand should be washed out. The proper wash rate will be approximately 47 gallons per minute, but the actual rate to give optimum results can only be determined by observing the condition of the sand before and after washing as above noted under "Filter Inspection" and revising wash rates accordingly.

CHLORINATOR

General

An electric-motor-operated hypochlorinator, together with a 10-gallon solution crock, is provided for sterilizing the filter effluent water.

Solution

The hypochlorite solution is mixed in the crock so that a solution of not greater than 1 percent strength results. HTH as manufactured by the Mathieson Alkali Works or Perchloron as manufactured by the Pennsylvania Salt Manufacturing Co. may be used. This material comes in 3¾- and 5-pound containers. One 3¾-pound container diluted to 30 gallons with water makes a 1 percent solution. The hypochlorite solution should be made up in one container, allowed to settle and decanted off into the container used as a suction tank for the feed solution. In this manner the sludge will be separated from the liquid and cannot clog the strainer.

Operation

The hypochlorinator is an adjustable stroke diaphragm pump which pumps the hypochlorite solution into the pipeline. The stroke may be adjusted and hence the quantity pumped by means of the double eccentric cam on the sides of the units. The quantity of solution to be used can only be determined by test. The units must be so adjusted that the residual chlorine content of the water in the visitors' building storage tank will be between 0.5 and 0.7 parts per million as determined by the orthotolidin test set furnished with the chlorinators (or adjusted in accordance with instructions from the resident public health engineer). A sight glass is installed on the suction hose in which the flow of solution can be observed. This should be regularly inspected, for occasionally the suction and discharge check valves on the hypochlorinator stick, resulting in reduced or no flow. The pump head can easily be removed and the rubber valves and seats cleaned when stoppage occurs. The manufacturer's operating instructions should also be followed.

CLEARWELL

General

The clearwell basin has a capacity between high- and low-water levels of 740 gallons and provides storage for the service pumps. With the service pumps shut down and the filters operating at 6.3 gallons per minute each, the vertical rise in level of water in the clearwell is 28.5 minutes per foot. Should any doubt arise as to the accuracy of the filter flow indicators, the quantity being discharged may be checked by this rise in level.

The clearwell is provided with a pressure-tight manhole and is vented through a 1-inch pipe which would discharge into the settling tank should any sudden increase in pressure occur in the clearwell. This 1-inch vent contains a float switch which stops all the chemical solution feeders when the surface elevation in the clearwell vent reaches 1324.69, at which time the filter rate will be reduced practically to zero and immediately the water surface in the filters and settling tank will approach elevation 1325.19, thereby causing raw water supply float valve to close. Any draft from the clearwell causing a drop in water level in the clearwell vent closes the float switch and normal operation is resumed.

SERVICE PUMPS

General

The two centrifugal service pumps deliver water from the clearwell to the storage tank in the basement of the visitors' building. Each pump has a capacity of 35 gallons per minute against a discharge head of 150 feet. The actual discharge head is only about 120 feet, but the capacity will remain practically the same irrespective of head. Both pumps may be operated together, but only one pump should be operated at a time under normal operation, with the second reserved as a spare.

Controls

A selector switch is provided so that either pump may be selected to operate on automatic control. The pumps should be alternated every week to equalize wear. The starting and stopping of the pump is controlled by a float switch on the visitors' building storage tank. A low-level float switch on the clearwell is also interlocked in this system to stop the service pump when the clearwell drops to low level.

Operation

The pump capacity of 35 gallons per minute is in excess of the filter capacity. With filters and one pump operating and starting with clearwell full, this difference in capacity will cause the clearwell level to fall. Although it will do no harm to the pumps to have them both operating, this would require manual control, for the clearwell would empty rapidly and the pump on automatic control would automatically shut off and the second require stopping by manual control. The manufacturer's operating instructions should be consulted for lubrication, operating difficulties, and other points.

OPERATING INSTRUCTIONS FOR RAW WATER SYSTEMS, WATAUGA PROJECT

(Reference drawings not included in this report)

GENERAL DESCRIPTION

Raw water is obtained from the penstock of each unit through an interconnecting 8-inch pipe and two 8-inch twin strainers located on floor elevation 1647 of the powerhouse. After being strained the water discharges into a 10-inch strained water header and is here divided into four separate systems. The normal pressure is 132 pounds per square inch with a minimum of 70 pounds per square inch and a surge pressure up to 210 pounds per square inch.

Strainers

A differential pressure switch is installed across the two twin strainers for the purpose of sounding a remote alarm. When strainer baskets are clean a normal differential pressure across them of approximately 1 pound exists. As the baskets become clogged this differential pressure increases until at 2½ pounds the switch operates to sound an alarm. This alarm warns the station operators that strainer baskets are becoming clogged and should be cleaned immediately. Strainers are arranged for cleaning without interruption of service. Refer to manufacturer's instructions for method of cleaning and servicing the strainers.

Special note: All factual information and special operations are included on the Valve Operation Diagram 47N305. The use of this written instruction is complete only when supplemented by that information.

Following are instructions for each of the four separate raw-water systems.

FIRE AND SERVICE SYSTEM—60 POUNDS PER SQUARE INCH

A complete pressure-regulating station is provided for reducing the pressure from a maximum inlet pressure of 145 pounds per square inch to a constant

outlet pressure of 60 pounds per square inch. The system consists of a 3-inch pilot-operated, pressure-reducing valve complete with globe valve bypass, a 4-inch pilot-operated, pressure-relief valve, and all necessary pressure gages, cut-off valves, and drain valves.

For operation and maintenance of the pressure-reducing valve, refer to manufacturer's instructions. If pressure-reducing valve is out of service, proceed as follows: Close inlet valve RS–1, outlet valve RS–3, and control valve RS–7. A globe valve RS–5 in the bypass is provided for manual regulation of the normal supply requirements and the adjacent pressure gauge will indicate when readjustment to approximately 60 pounds per square inch is required. As the demand increases from normal, such as in case of fire, this valve would require immediate readjustment. When the demand decreases from normal the resulting buildup in pressure will cause the relief valve to operate until the globe valve is readjusted or the pressure-reducing valve is restored to service.

The pressure-relief valve is set to relieve at 75–83 pounds per square inch and should be checked to make certain that it opens at the proper pressure. Discharge from relief valve flows directly to tailwater. A check valve is provided to eliminate the possibility of tailwater flooding into powerhouse if relief valve is ever removed from system for repairs during periods of high flood. The fire and service system (60 pounds per square inch) provides the following four services:

Fire

Water is obtained for fire protection of the powerhouse, control building, and the switchyard equipment. Located at strategic points throughout the powerhouse are seven semiautomatic-type fire hose racks each complete with 75 feet of 1½-inch unlined linen hose with a 1-inch nozzle. Two similar fire hose racks are located in the control building. Located in the switchyard are four 6-inch fire hydrants, each having two 2½-inch hose connections and supplied through a 6-inch main from the powerhouse. The hydrants are located so that any part of the switchyard, including the adjacent control building, may be served with water by connecting two 50-foot lengths of 2½-inch hose, in series, to the proper hydrant. Two 50-foot lengths of hose are provided, reeled on a portable fire hose cart. The hose cart is stored in a separated portion of the insulating oil purification building located in the switchyard. Two atomizing hose nozzles are provided which prevent injury, by electrical shock, to the operator when directing water upon live electrical equipment.

Lawn sprinklers

Water is obtained from the 6-inch main to the switchyard for lawn sprinklers in seeded areas adjacent to the control building and parking spaces. Sprinklers and hose may be connected to permanently installed street washers.

Service

Water is obtained for service connections. Scattered throughout the powerhouse, control building, and switchyard oil purification building are numerous 1-inch service hose outlets for floor flushing and any other services requiring raw water.

Auxiliary cooling (control building)—air-conditioning equipment

Water is obtained from the 60-pound-per-square-inch system for use in cooling coils of the air-conditioning equipment located in the control building. For detailed instructions on the operation of these systems, refer to "Operating Instructions—Heating, Ventilating, and Air-Conditioning Systems."

STATION DRAINAGE SUMP EDUCTOR—132 POUNDS PER SQUARE INCH NORMAL

A 6-inch eductor in the station drainage sump is supplied with high-pressure water through a 4-inch main connected to the 6-inch line supplying the fire and service pressure reducing station. This supply is controlled near the eductor by a globe valve (valve RE–1). For operation of the eductor refer to "Operating Instructions—Unwatering, Filling, and Drainage Systems."

UNIT COOLING SYSTEM—40 POUNDS PER SQUARE INCH

A complete pressure-regulating station is provided for reducing the pressure from a maximum inlet pressure of 145 pounds per square inch to a constant outlet pressure of 40 pounds per square inch. The system consists of two 4-inch pilot-operated pressure-reducing valves operating in echelon, complete with globe valve bypass, an 8-inch pilot-operated pressure-relief valve, and all necessary pressure gages, cut-off valves, and drain valves.

For operation and maintenance of pressure-reducing valves refer to manufacturer's instructions. If either pressure-reducing valve is out of service, proceed as follows: Close the proper inlet, outlet, and control valves, and throttle globe valve bypass RC–9 as necessary to supplement the output of the remaining pressure-reducing valve, until adjacent pressure gauge indicates 40 pounds per square inch.

The pressure-relief valve is set to relieve at 44–50 pounds per square inch and should be checked to make certain that it opens at the proper pressure. Discharge from relief valve flows directly to tailwater. A check valve is provided to eliminate the possibility of tailwater flooding into powerhouse if relief valve is ever removed from system for repairs during periods of high flood.

The unit cooling system (40 pounds per square inch) serves the following (valve numbers mentioned are for unit 1 and corresponding valves for unit 2 are prefixed by the number 2):

Generator

Water is provided for use as a cooling medium in the six generator surface air coolers and in the cooling coils of the generator guide and thrust-bearing oil reservoir. A motor-operated valve 1RC–1 serves as a complete shutoff for all water to the unit. After passing through this valve the supply divides, entering the air coolers through valve 1RC–3, and the bearing oil cooling coils through valve 1RC–17. The generator bearing water supply line is equipped with an indicating flowmeter having two electrical contacts operating on low flow; one contact is interlocked with starting controls to prevent starting the unit at low flow, and the other contact sounds an alarm. The generator air cooler supply line is equipped with an indicating flowmeter having two electrical contacts operating on low flow; one contact sounds an alarm and the other contact shuts down the unit; the shutdown contact is also interlocked with starting controls to prevent starting the unit at low flow. Both discharges are carried to tailwater. Flow through the bearing oil cooling coils is regulated by manually throttling valve 1RC–20. Flow through the air coolers is controlled automatically by a motor-operated proportioning valve operated by a temperature bulb in the generator housing.

Flow through discharge valve 1RC–20 should be regulated for proper operating temperatures (see manufacturer's instructions) as determined by observation of the 16-point temperature recorder located on governor actuator panel. Never throttle supply valves 1RC–3 and 1RC–17.

Turbine

Water is used for runner seal rings, bearing packing box, and as a cooling medium for the bearing oil cooler. Supply valve 1RC–21, located in pipe gallery, serves as a complete shutoff for all water to turbine. An indicating flowmeter is provided in the main supply to the turbine. This meter has 2 electric contacts operating on low flow, 1 for alarm and 1 to shut down the unit; the shutdown contact is interlocked with starting controls to prevent starting the unit at low flow. Water flow through the oil cooler is controlled by throttling valve 1RC–22 in the discharge line to tailwater. Never throttle valve 1RC–21.

Note: The motor-operated valve 1RC–1 is opened or closed by manual remote control from the control building at the same time other unit auxiliaries are started or stopped. The operator in charge shall be instructed to wait approximately 5 minutes after the unit is shut down before closing valve 1RC–1.

An antisyphon arrangement is provided to prevent draining of air coolers while unit is shutdown. If necessary to drain an air cooler this may be done by removing drain plugs from the head cover flange of the cooler. A drain

plug is provided in the discharge water header also. Drainage is collected by a circular gutter around the unit and discharged into the station drainage system.

TRANSFORMER SPRINKLER SYSTEM

Each transformer is provided with a pipe system supplying strained raw water from the 10-inch main header at full penstock pressure (normal 132 pounds per square inch). Each pipe system feeds 64 sprinkler nozzles located so as to cover a transformer completely in event of fire. Each pipe system is controlled by a hydraulically operated valve operated by a solenoid pilot valve. For instructions on operation and design characteristics refer to Valve Operation Diagram 47N305.

OPERATING INSTRUCTIONS FOR POWERHOUSE AND CONTROL BUILDING HEATING, VENTILATING, AND AIR CONDITIONING, BOONE PROJECT

POWERHOUSE

General

a. The powerhouse is ventilated and partially heated. No air conditioning is required. Mechanical ventilation is provided according to the need for comfort, for the removal of heat from electrical equipment and solar radiation on roofs, walls, and decks, and for the relief of dampness. Electric air heaters serve to warm areas where maintenance or repair operations may be expected and where freezing may occur.

Heating

a. All heating is by 220- or 440-volt unit blower-type air heaters strategically located throughout the powerhouse, with the exception of three 220-volt recessed heaters in the lobby, corridor, and toilet. All blower-type heaters are thermostatically controlled, and are provided with auxiliary mounted "Hand-Off-Auto" switches. These heaters may be placed either on automatic operation as controlled by the thermostat, on positive operation independent of the thermostat, or cut off entirely at the option of the operators. The recessed heaters are thermostatically controlled with the thermostat wired in series with the service so only "Automatic" operation or "Off" can be selected by the operators.

b. In addition to the permanently connected heaters, power outlets are provided at convenient locations throughout the powerhouse for 18-kilowatt, 440-volt, pedestal-mounted and 3-kilowatt, 220-volt, floor-mounted blower-type portable heaters.

Ventilating

a. The generator room is ventilated by the generator room exhaust fan, mark 47N751–2, located in the fan room. Air is drawn through wire guard and damper assemblies located in the downstream wall of the generator room. An automatic electric-motor-driven damper in the fan discharge duct closes upon fan stoppage to prevent infiltration of air. The system is controlled by a single "On-Off" switch located in the fan room. Manual dampers located in the intake wire guard and damper assemblies should be closed in cold weather to prevent infiltration of cold air.

b. The service bay is ventilated by the service bay exhaust fan, mark 47N751–1, located in the fan room. Air is drawn through a grating located at the western end of the draft tube deck and passes through the pipe gallery and draft tube access gallery to oil purification room and machine shop where it is collected in a duct system connected to fan inlet. Entrained moisture of outside air is removed upon entrance to the pipe gallery by an eliminator. An automatic electric-motor-driven damper in the fan discharge duct closes upon fan stoppage. The service bay exhaust fan is controlled by an "On-Off-Remote" switch located in the fan room and an "On-Off" switch located in the machine shop. The manual damper located at the air intake point should be closed in cold weather to prevent infiltration of cold air.

c. The toilet, shower, and janitor's closet are ventilated by the toilet exhaust fan, mark 47N751-3, connected by a duct system to these spaces and located in the fan room. Air is drawn into these spaces through louvered doors. An automatic electric-motor-driven damper in the fan discharge duct closes upon fan stoppage to prevent infiltration of air. The system is controlled by an "On-Off" switch located in the lighting cabinet.

d. The entire cable and leads tunnel is ventilated by the leads tunnel exhaust fan, mark 47N751-6, located at the western end of the tunnel. Air is drawn through a grating in the tunnel at the switchyard end and passes through the entire length to the vaneaxial fan located in a niche at the powerhouse end. Air is discharged through a louver in the downstream powerhouse wall above the deck. This system is controlled by an "On-Off-Remote" switch located near the fan and "On-Off" switches located near the powerhouse and control building entrances to the tunnel.

e. The turbine pits are ventilated by propeller fans, mark 47N751-9. These fans are controlled by "On-Off" switches located adjacent to the fans.

CONTROL BUILDING

General

a. Complete air conditioning is provided for the control room, lobby, test rooms, offices, and communication room for the protection of delicate electric equipment and for human comfort. The rest of the building is heated and ventilated as required for the operator's comfort or for the relief of dampness. A mechanical-electrical control and operation diagram of the control building systems is shown in plate 40, page 598, and airflow diagrams are shown in plate 58.

Heating

a. The control room, lobby, test rooms, offices, and communication room are heated by thermostatically controlled facilities of the air-conditioning systems. The janitor's closet and vestibules are heated by thermostatically controlled, recessed, wall-mounted, 220-volt gravity connection heaters. The locker room is heated by a blower-type heater recessed in the furred space above the lockers. All other areas requiring heat are heated by thermostatically controlled 220- or 440-volt blower-type unit heaters with "Hand-Off-Auto" auxiliary mounted control switches.

b. In addition to the permanently connected heaters, power outlets are provided at convenient locations throughout the control building to permit the use of the 18-kilowatt, 440-volt pedestal-mounted or 3-kilowatt, 220-volt floor-mounted blower-type portable heaters purchased for the powerhouse.

Ventilating

a. The toilets, file rooms, janitor's closet, kitchens, locker room, dark room, and shower are ventilated by a 2-speed toilet exhaust fan, mark 47N851-7, connected by a duct system to these spaces and located in the air-conditioning room. Air is drawn into all these spaces except the locker room and shower through louvered doors. Air to the locker room and shower is pulled through a concealed duct from the control room. An automatic electric-motor-driven damper, mounted on the fan discharge, closes upon fan stoppage to prevent infiltration or backup from other active exhaust systems. The fan is controlled from an "On-Off-Auto" selector switch on the air-conditioning control board. In the "On" position the fan runs independent of any other control and may be run at "Fast" or "Slow" as selected by the "Fast-Slow" switch on the control board. In the "Auto" position the fan is run at a speed as determined by the setting of the office air-conditioning system master selector switch on the control panel irrespective of the setting of the "Fast-Slow" switch. The fan runs at "Fast" on a setting of "Cool" or "Vent" on the office air-conditioning system master selector switch or at "Slow" on a setting of "Heat." For all normal operation the toilet exhaust fan selector switch should be left on the "Auto" setting.

b. The spreading room and basement storage room are ventilated by electrical spaces exhaust fan, mark 47N851-4, connected by a duct system to these spaces and located in the air-conditioning room. Air is supplied to these spaces through a duct system from electrical spaces supply fan, mark 47N851-2, located in the air-conditioning room. Automatic electric-motor-driven

dampers are located on both fan discharges, which close upon fan stoppage to prevent infiltration or backup from other active exhaust systems. The exhaust fan is controlled by an "On-Off" switch located on the air-conditioning control board. The supply fan is controlled by an "On-Off-Auto" switch located on the control board. In the "On" position the supply fan will operate irrespective of the operation of the exhaust fan. In the "Auto" position the supply fan operates whenever the exhaust fan is operated. For all normal operation the electrical spaces supply fan selector switch should be left on the the "Auto" setting.

c. The relay room is ventilated by the relay room exhaust fan, mark 47N851–8, by a duct system. Air is drawn into the room through an outside air connection consisting of louver, filter, and damper. An automatic electric-motor-driven damper, mounted on the fan discharge, closes upon fan stoppage to prevent infiltration or backup from other active exhaust systems. The filters should be observed at frequent intervals of not more than 7 days to prevent an excessive accumulation of dust. The air to the relay room must be dust free at all times. The register on the face of the intake plenum should be closed when the ventilation is off in cold weather to prevent the infiltration of cold air. The fan is controlled by an "On-Off-Remote" selector switch on the air-conditioning control board and a wall-mounted "On-Off" switch in the relay room. When the control board switch is in the "On" position the fan will operate irrespective of the position of the room switch. In the "Remote" position the fan is controlled entirely by the room switch. For all normal operation the control board switch should be left on the "Remote" setting.

d. The battery room and motor-generator room are ventilated by the battery room exhaust fan, mark 47N851–5, connected by a duct system to these spaces and located in the air-conditioning room. Air is supplied to these spaces through a duct system from the electrical spaces supply fan, mark 47N851–2. (See paragraph "b.") An automatic electric-motor-driven damper, mounted on the fan discharge, closes upon fan stoppage to prevent infiltration or backup from other active exhaust systems. The fan is controlled by an "On-Off-Remote" selector switch on the air-conditioning control board and a wall-mounted "On-Off" switch in the battery room. When the control board switch is in the "On" position the fan will operate irrespective of the position of the battery room switch. In the "Remote" position the fan is controlled entirely by the room switch. For all normal operation the control board switch should be left on the "Remote" setting.

e. The air-conditioning room and water purification room are ventilated by the mechanical spaces exhaust fan, mark 47N851–6, connected by a duct system to these spaces and located in the air-conditioning room. Air is drawn into these spaces through a louver from the areaway outside the air-conditioning room. An automatic electric-motor-driven damper, mounted on the fan discharge closes upon fan stoppage to prevent infiltration or backup from other active exhaust systems. The fan is controlled entirely by an "On-Off" switch located on the air-conditioning control board.

CENTRAL COOLING EQUIPMENT

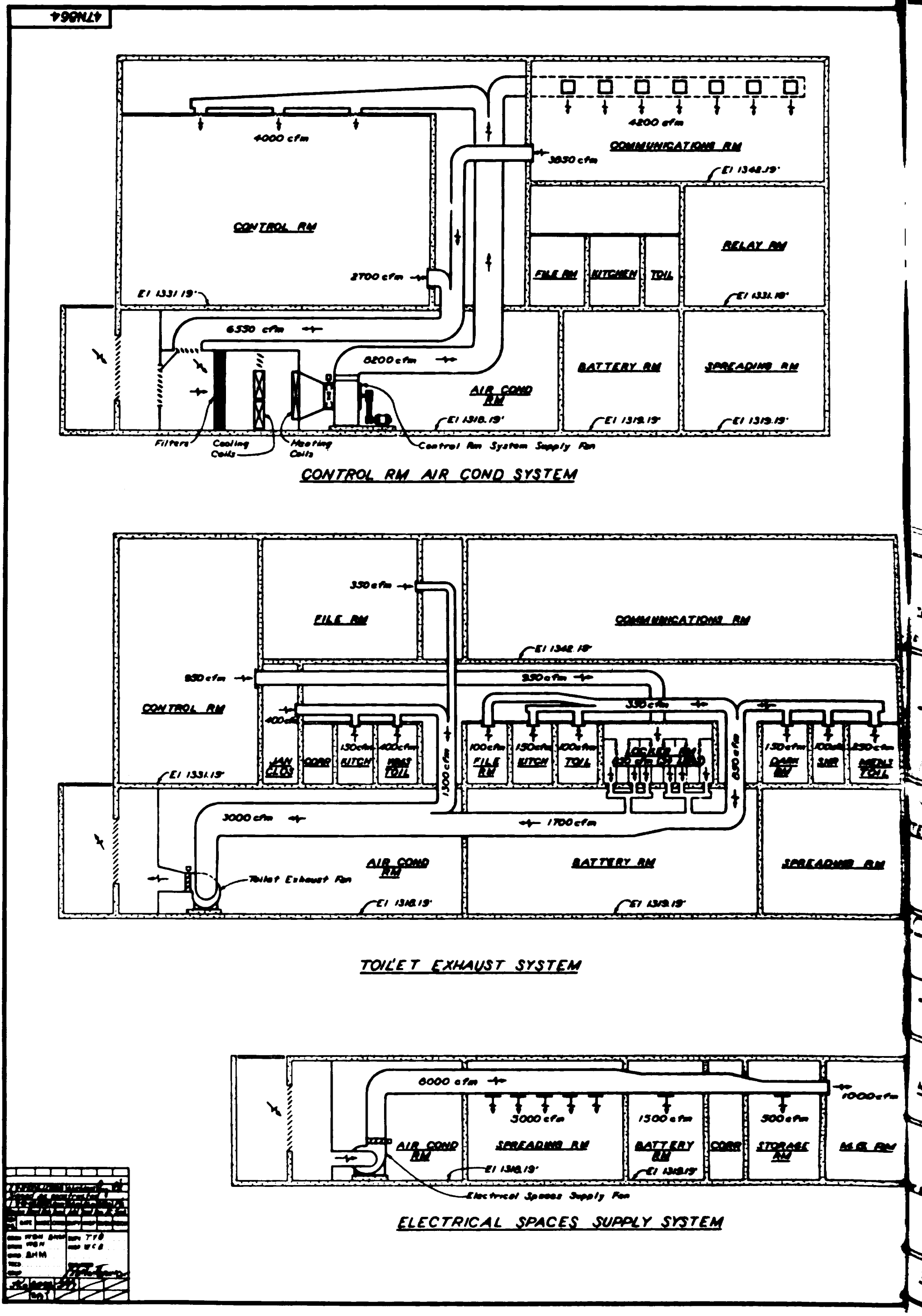
General

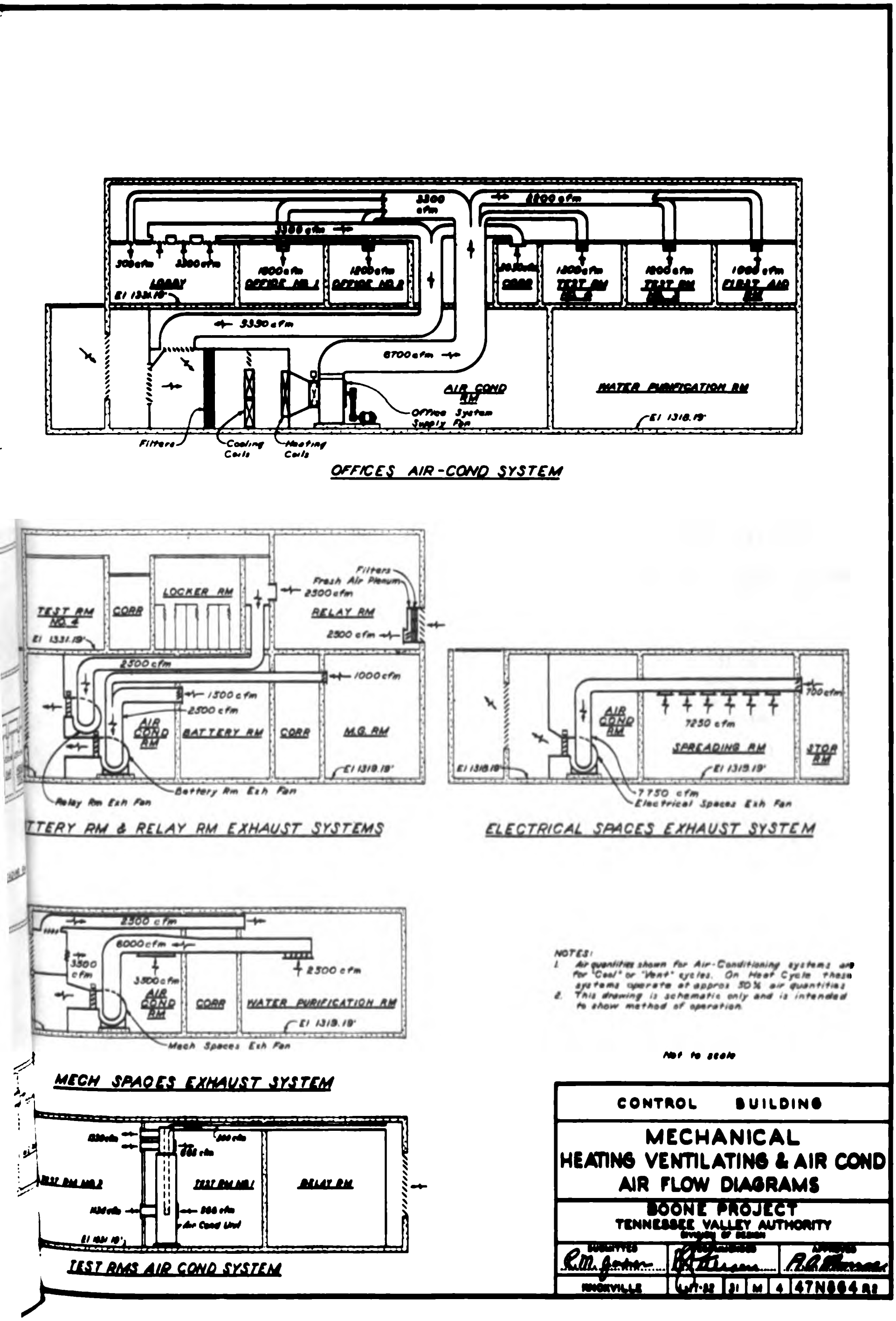
a. All cooling is accomplished by circulated chilled water from the central cooling equipment.

b. Chilled water is stored in the chilled water storage tank and circulated by the chilled water pump through a header to the two air conditioning systems. The chilled water is allowed to pass through any of the coils or to be bypassed as called for by the three-way water mixing valve, controlled by a thermostat located in the return duct. The water, from all the coils, is then passed through the water cooler where it is chilled as called for by thermostat, mark 8, located in the chilled water storage tank. The water then returns to the storage tank, completing the chilled water circuit. The thermostat, mark 7, should be set to break contact when the water temperature drops below 45 degrees.

c. Condensing is accomplished by passing raw water through the condenser, and after passing through the condenser it is discharged to waste.

d. The compressor, motor, drive, water cooler, condenser, and refrigerant controls and safety devices are furnished by York Corp., requisition 666623, order C–51–26193.


4000 cfm
4200 cfm
COMMUNICATIONS RM
3830 cfm
El 1348.19'
CONTROL RM
RELAY RM
2700 cfm
FILE RM
KITCHEN
TOIL
El 1331.19'
El 1331.19'
6530 cfm
8200 cfm
AIR COND RM
BATTERY RM
SPREADING RM
El 1318.19'
El 1319.19'
El 1319.19'
Filters
Cooling Coils
Heating Coils
Control Rm System Supply Fan
CONTROL RM AIR COND SYSTEM
350 cfm
FILE RM
COMMUNICATIONS RM
El 1342.19'
850 cfm
350 cfm
CONTROL RM
330 cfm
400 cfm
150 cfm
400 cfm
100 cfm
150 cfm
100 cfm
150 cfm
100 cfm
250 cfm
1300 cfm
830 cfm
JAN CLOS
CORR
KITCH
FILE RM
KITCH
TOIL
LOCKER RM
DARK RM
SHR
MEN'S TOIL
El 1331.19'
3000 cfm
1700 cfm
AIR COND RM
BATTERY RM
SPREADING RM
Toilet Exhaust Fan
El 1318.19'
El 1319.19'
TOILET EXHAUST SYSTEM
6000 cfm
1000 cfm
3000 cfm
1500 cfm
500 cfm
AIR COND RM
SPREADING RM
BATTERY RM
CORR
STORAGE RM
M.G. RM
El 1318.19'
El 1318.19'
Electrical Spaces Supply Fan
ELECTRICAL SPACES SUPPLY SYSTEM


OFFICES AIR-COND SYSTEM
3300 cfm
2100 cfm
3330 cfm
6700 cfm
LOBBY
OFFICE NO. 1
OFFICE NO. 2
CORR
TEST RM
FIRST AID RM
AIR COND RM
WATER PURIFICATION RM
El 1318.19'
Office System Supply Fan
Filters
Cooling Coils
Heating Coils
Filters
Fresh Air Plenum
2500 cfm
TEST RM NO. 4
CORR
LOCKER RM
RELAY RM
El 1331.19'
1000 cfm
1500 cfm
2500 cfm
AIR COND RM
BATTERY RM
CORR
M.G. RM
El 1319.19'
Battery Rm Exh Fan
Relay Rm Exh Fan
TTERY RM & RELAY RM EXHAUST SYSTEMS
700 cfm
7250 cfm
AIR COND RM
SPREADING RM
STOR RM
El 1318.19'
El 1319.19'
7750 cfm
Electrical Spaces Exh Fan
ELECTRICAL SPACES EXHAUST SYSTEM
2300 cfm
6000 cfm
3300 cfm
3300 cfm
2500 cfm
AIR COND RM
CORR
WATER PURIFICATION RM
El 1319.19'
Mech Spaces Exh Fan
MECH SPACES EXHAUST SYSTEM
NOTES:
1. Air quantities shown for Air-Conditioning systems are for "Cool" or "Vent" cycles. On Heat Cycle these systems operate at approx 50% air quantities.
2. This drawing is schematic only and is intended to show method of operation.
Not to scale
TEST RM NO. 1
RELAY RM
Air Cond Unit
TEST RMS AIR COND SYSTEM
CONTROL BUILDING
MECHANICAL
HEATING VENTILATING & AIR COND
AIR FLOW DIAGRAMS
BOONE PROJECT
TENNESSEE VALLEY AUTHORITY
KNOXVILLE
47N864

Description of equipment

a. *Compressor.* The compressor is a York 6-cylinder reciprocating compressor designed for use with Freon 12. The compressor is rated at 39 tons of refrigeration at 37.5-degree suction and 103.5-degree condensing temperature, with the following characteristics: revolutions per minute 1,305, bore 3¾ inches, stroke 3 inches, and piston speed 652.5 feet per minute.

b. Motor and drive. The motor is a standard 40-horsepower, 1,170-revolution-per-minute, 440-volt, 3-phase, 60-cycle Allis-Chalmers type AP, driving the compressor through an Allis-Chalmers v-belt drive of six "C" section belts.

c. *Condenser.* The condenser is a 4-pass York horizontal shell and tube, 14 inches in diameter by 7 feet 1½ inches long, rated at 39 tons of refrigeration when supplied with 100 gallons per minute of incoming water at 85°.

d. *Water cooler.* The water cooler is a 1-pass York horizontal shell and tube, 14 inches in diameter by 9 feet 10 inches long rated at 39 tons of refrigeration, with 90 gallons per minute of entering water at 54° and an evaporating temperature of 37.5°.

Operation of system

a. To start the central cooling equipment proceed as follows:

(1) Fill the chilled water storage tank.
(2) Open all water coil and pump valves.
(3) Check all motor fuses.
(4) Check for correct overload relay element ratings.
(5) See that the crankcase oil level is even with the top snifter.
(6) Check all motor-bearing lubrications.
(7) Start both the chilled water pump from the control board. This pump is interlocked with the compressor so that it must be running before the compressor can start.
(8) Start the compressor by turning the twist button on the compressor panel on the control board to either "On" or "Auto." (In the "On" position the compressor will operate without any control from the chilled water storage tank but is adequately protected by its safety devices. In the "Auto" position the compressor is started and stopped by the action of the thermostat in the chilled water storage tank.)
(9) Stop the compressor if its oil level drops appreciably.

b. If the central cooling equipment fails to produce any cooling, open the circuit breakers of the pump and compressor and check as follows:

(1) Examine all fuses.
(2) Check to see if there is water to the condenser.
(3) See that the overload relay in the motor starter is reset.
(4) Check to see that the cut-outs and differential pressure switches are operating properly.

c. If the central cooling equipment is to remain idle for a few days or longer, the operator should proceed as follows:

(1) Start the pump.
(2) Close the liquid valve.
(3) Start the compressor and let it run until the low-pressure cutout stops it. Now hold in the low-pressure cutout and run the compressor until the suction pressure drops to zero. Let the compressor stand idle for about 5 minutes and repeat. Then close the compressor suction and discharge valves.
(4) Stop the pumps and open the compressor and pumps' disconnect switches.

Controls and safety devices

a. The compressor is started by turning the selector switch on the control board to either "On" or "Auto."

b. When the selector switch is turned to the "On" position, the control circuit is placed in series with the pump's auxiliary contacts, high-pressure cutout, low-pressure cutout, differential pressure switch, and chilled water low temperature cutout (set at 35° minimum). If the pump is running and all the safety devices are satisfied, current will flow through the holding coil of the compressor starter causing it to close and start the compressor.

c. When the compressor is started, an auxiliary contact on the starter is closed, allowing control current to flow through two capacity reduction solenoid valves. These two solenoid valves provide two steps of capacity of 33⅓ percent and are controlled by thermostats, mark 8, mounted in the chilled water tank. These thermostats should be set to operate at 47° and 49° or below.

d. When the selector switch is turned to the "Auto" position, controlling thermostat, mark 7, is placed in series with all the safety devices, hereinbefore mentioned, to allow control current to flow through the holding coil of the compressor starter only when cooling is needed. It should be set to maintain water stored in the tank at 45°.

Charging gas

a. To make the initial charge of Freon 12, the system should be evacuated as completely as possible before any Freon is charged into the system. Upon evacuation of the system, Freon may be added as outlined below.

b. As a general rule the need for Freon in systems of this type is indicated by excessive compressor running with reduced refrigeration effect and low suction pressure.

c. Freon is charged into the system through the charging valve as follows:

(1) Connect Freon cylinder to charging valve.
(2) Close Freon liquid valve.
(3) Throttle compressor suction valve.
(4) Open charging valve and Freon cylinder valve.
(5) Start the water pump.
(6) Start the compressor and run until required amount of refrigerant has been charged.

DETAILED OPERATION OF CENTRAL AIR-CONDITIONING SYSTEMS

General

a. Complete year-round air conditioning, consisting of heating, cooling, or ventilation, is provided for the offices, test rooms 3 and 4, first-aid rooms, control room, and communication room. Each group of related spaces is served by a complete built-up system, consisting of filters, chilled water cooling coils, electric blast heater, humidifier, dampers, controls, and 2-speed motor-driven fans.

b. Each system can be put on heating, cooling, or ventilation, independent of any other, by means of a selector switch on the control panel of the control board. When any system is put on any operation, the control circuits for that phase of operation only are energized, all others remaining deenergized.

c. Cooling is accomplished by the air passing over finned-tube water coils, through which chilled water from the chilled water storage tank is passed.

d. Heating is accomplished by the air passing over finned-element electric blast heaters. Humidity is accomplished by the release of live steam directly into the air stream.

e. Ventilation is accomplished by the circulation of fresh outside air through the space.

Cooling cycle

a. To put either system on the cooling cycle:

(1) Start the central cooling equipment as outlined previously.
(2) Close the manually operated bypass damper in the plenum.
(3) Turn the selector switch on the control panel to "Cool."
(4) Turn the fan switch to "Auto."

b. When the selector switch is turned to "Cool," only controls relative to cooling are energized.

c. The flow of chilled water through the cooling coils is controlled by three-way, double-seated motor-operated valves controlled by thermostats, mark 5, located in the return duct, and which are compensated by thermostats, mark 6, located in the fresh air duct. The thermostats should be so adjusted to produce a temperature of 76° dry bulb in the conditioned spaces until the outside air rises to 85° dry bulb. As the outside temperature continues to rise, the thermostat, mark 6, overrides the controlling thermostat, mark 5, so that when the outside air temperature reaches 95° dry bulb, the inside temperature shall be 80° dry bulb.

d. When the selector switch is moved away from "Cool," it opens a contract which breaks the blue to white circuit between the valve, mark 18, and the thermostat, mark 5, which causes the valve motor to drive the valve to a fully bypassed position.

e. An automatic mixing damper is provided in each system between the return and fresh air connections. The damper consists of 2 sections, 1 in fresh air and 1 in return air interconnected so that when one is opened the other is closed, admitting fresh air, return, or a controlled mixture of both. The motor that operates this damper is controlled by thermostat, mark 10, which should be set to bring the fresh air damper from a fully closed position at 40° to a fully open position at 60° and thermostat, mark 11, which should be set to bring the fresh air damper from a fully open position at 75° to a fully closed position at 95°. The linkage to the fresh air damper should be so adjusted that it will allow a small amount of fresh air to be admitted at all times.

f. Both systems have zone duct controls, consisting of motor-operated dampers, thermostats, and switchover contacts on the master selector switches. The switchover contacts allow the correct operation of the branch duct damper motors for either heating or cooling. The air supplied to a given space is controlled by a room thermostat, mark 1, which is compensated by a thermostat, mark 6, located in the fresh air supply. The thermostats should be so adjusted to produce a room condition of 76° dry bulb while the outside temperature rises to 85° dry bulb. As the outside temperature continues to rise, the thermostat, mark 6, overrides the room thermostat, mark 1, so that when the outside temperature reaches 95° dry bulb, the inside temperature shall be 80° dry bulb.

g. Both systems are provided with static pressure controls to maintain a constant pressure in the ducts to prevent an excess of air being supplied to any outlet. Each fan has a motor-operated inlet damper controlled by a static pressure regulator, mark 16, which measures the static pressure in the duct leading from the fan discharge. The static pressure regulator, mark 16, should be set to have the inlet damper fully open when all the duct branch dampers are open and to move toward a closed position when any of the duct branch dampers start to close.

h. A draft gauge is provided to indicate the pressure drop across the filters to indicate when the filters are loaded sufficiently with dirt to require reloading. The filters should be reloaded when the pressure drop across them rises to one-half inch of water.

Heating cycle

a. To put either system on the heating cycle:

(1) Open bypass damper in plenum.
(2) Turn the selector switch on the control panel to "Heat."
(3) Turn the fan switch to "Auto."

b. When the selector switch is turned to "Heat," only controls relative to heating are energized.

c. The blast heater in each system is composed of three equal capacity circuits each controlled by a thermostat, mark 8, mounted in the return air. The settings of these thermostats should be staggered to make contact at 70°, 71°, and 72°.

d. A limit thermostat, mark 9, is provided with its sensitive bulb mounted adjacent to the heater face to break the circuits to all heater contactor coils upon excessively high temperature. This thermostat should be set to break contact at 140°.

e. Humidity is provided by the emission of water vapor to the air stream from a tank of boiling water. The water is heated by a 9-kilowatt immersion heater controlled by a humidistat, mark 14, mounted in the return duct. Upon a drop in humidity, the humdistat will energize the immersion heater until the humidistat is satisfied. The humidistat should be set to operate at 45° relative humidity. Careful check on, calibration of settings should be made at the beginning of each heating season with a psychrometer.

f. The static pressure control is made inoperative during the heating cycle by contact points on the main system selector switch, which deenergizes the control circuit on the heating cycle.

g. The zone damper control is in operation on the heating cycle as well as cooling. Extra contact points on the main system selector switch provide double-pole, double-throw switching for each zone damper circuit which auto-

matically puts the thermostats, mark 1, and branch dampers on the correct sequence of controls.

Ventilation cycle

a. To put either system on the ventilation cycle:

(1) Open the manually operated bypass damper in plenum.
(2) Turn the selector switch on the control panel to "Vent."
(3) Turn the fan switch to "Auto."

Test rooms Nos. 1 and 2

a. The test rooms Nos. 1 and 2 are provided with heating and cooling by a 5-horsepower Nevinger air-conditioning unit supplying air to both rooms. Fresh air is supplied through a duct connected to the outside air side of the relay room filter assembly. Selection of either heating or cooling is made by the "Summer–Winter" selector switch mounted on the machine.

b. Summer setting provides cooling by operation of the refrigerant cycle, which is controlled by a cooling thermostat.

c. Winter setting provides heating by the operation of a 15-kilowatt air-type blast heater mounted inside the unit, which is controlled by a heating thermostat.

Conclusion

a. In the preceding discussion of the controls and operation of the air-conditioning systems, the settings of a number of control devices were specified. If, after full and complete operation of the system for a period of not less than a week, there appears to be a need for altering the designated setting of any device to better serve the affected space or occupants, changes may be made only by the operator in charge.

b. Tampering with the setting of any device by a nonresponsible person should be avoided at all times.

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